LEMELSON-MIT JV InvenTeams™


# STUDENT GUIDE

Name

School

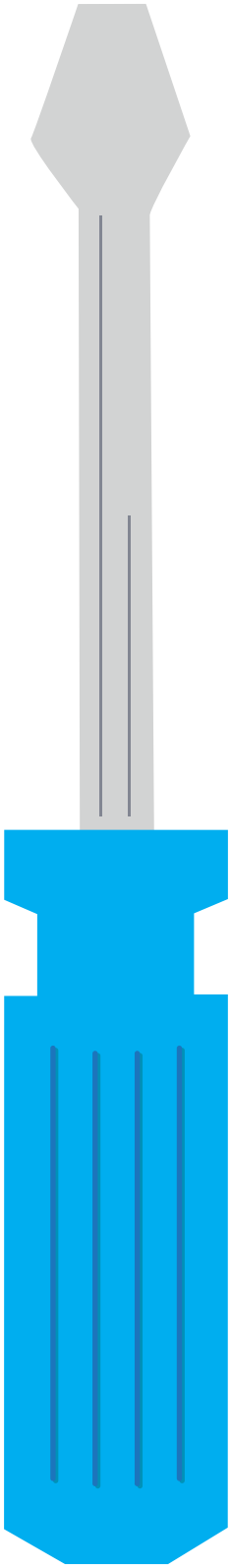
Grade

## ACTIVITY OVERVIEW



## MEETINGS

# INTRODUCTION TO JV INVENTEAMS



## SHOE SOLES

**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

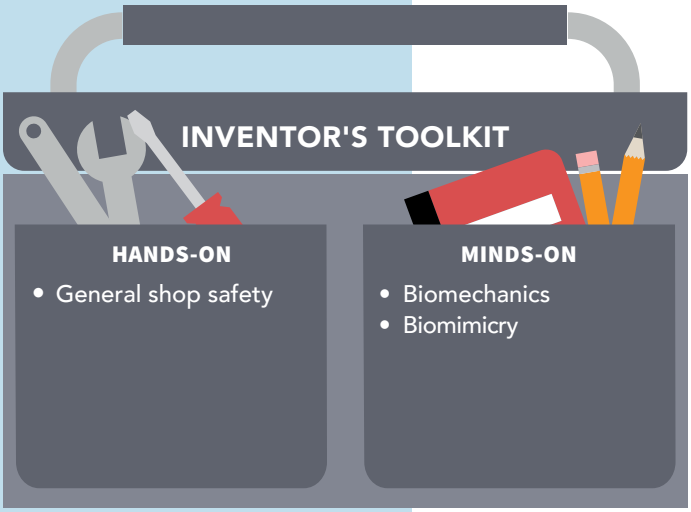
The goal of JV InvenTeams is to cultivate new ways of thinking and develop technical skills for students with limited access to hands-on STEM enrichment opportunities. Through prescribed activities, students will add to their own "toolkits" of minds-on knowledge and hands-on skills while having fun!

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.




**Each unit has the following in the first pages:**

- Title page with summary of the unit and learning objectives
- Synopsis 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

## 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.

**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.**

LEMELSON-MIT InventTeams

**You may ask, "Why should I invent?" Here are some of the reasons.**

**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 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 you 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)*

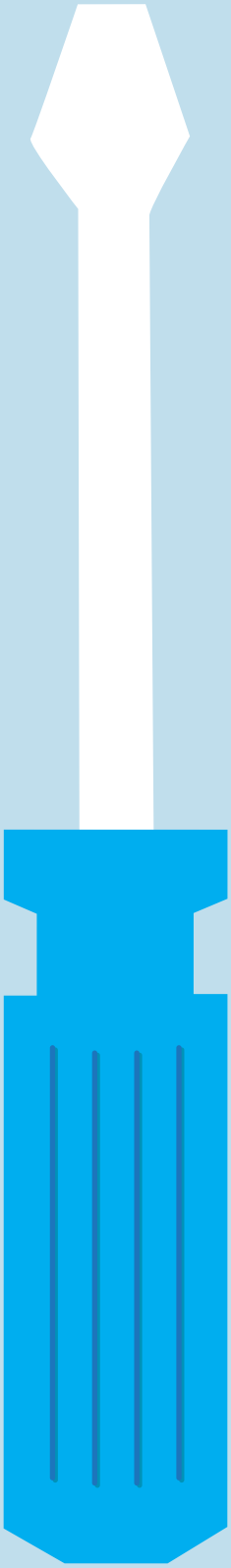
**A** = **Adapt** *(how would you eat your spaghetti without a utensil?)*

**M** = **Magnify** *(how would your chair function if 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 first stating the problem you would like to solve, which defines the challenge. After determining the challenge, it's a matter of asking questions about using SCAMPER to guide you. No idea is a "good" or "bad" idea at this point.

## Documentation

It is highly encouraged that you document your 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 your Student Guides. Remember to routinely review your guide, adapting what you 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/.**

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

This unit will guide you to create shoe soles that meet the needs of a chosen user.

You will learn about the biomechanics of the human foot in action. You will research treads and thicknesses of various athletic shoes to observe differences and similarities. You will also look toward nature (biomimicry) for insight. You will pick a specific athletic activity such as basketball in your small teams for the design of a shoe sole. You will design a shoe sole and use clay to create a model of your sole after researching the activity and interviewing prospective users. You will create molds of the clay model and will use polyurethane compounds to create your shoe sole prototypes.

You will gain both minds-on and hands-on skills in this unit to begin expanding your toolkit. Minds-on skills include learning about biomechanics, biomimicry, and the design process – identifying a problem, brainstorming, researching, interviewing prospective users, sketching ideas, building, and testing. Hands-on skills include learning to cut and fold cardboard, sculpting clay models, and practicing the molding process. You will draw from these new skills toward the end of the unit to brainstorm an invention of your own. You might think of additional materials to design a low-cost shoe, or maybe you will use the molding process to create a completely different device. You will learn to be inventive thinkers as you progress through this unit and others.

### Learning Principles

- Design Process
- Forces
- Biomechanics
- Biomimicry
- Materials
- Molding

## 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 Biomechanics & Biomimcry

Learn about biomechanics and how footwear is designed to meet specific needs. Learn about biomimicry as a method for brainstorming designs. You will be introduced to the main design challenge of the unit and assigned to a small team. Research the shoe soles of a chosen activity.

### 3 Sketch & Design

Learn to draw to scale and how to make **isometric** and orthographic **drawings** of your shoe soles.

### 4 Sculpt Clay Models

Finalize a shoe sole design and use modeling clay and tools to make 3D models of the soles. Team members share designs and select one model for casting.

### 5 Cast Clay Models

Prepare a molding box. Cast the selected shoe sole model in VytaFlex® 30. In the remaining time, meet Gihan Amarasiriwardena, a footwear inventor and clothing designer.

### 6 Shoe Sole Prototypes

Remove the clay model and have a mold of the shoe sole. Cast your prototype in VytaFlex 30. Learn about real-world shoe design from a designer at Columbia Sportswear Company. Use your toolkit of new skills to brainstorm ideas for an invention using shoe design, biomimicry, and/or the molding process.

### 7 Test Prototypes & Invention Ideas

Test out your shoe soles and provide feedback to other teams. Conceptualize a new purposeful invention that uses shoe design, biomimicry, and/or the molding process.

# SHOE SOLES
## 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.

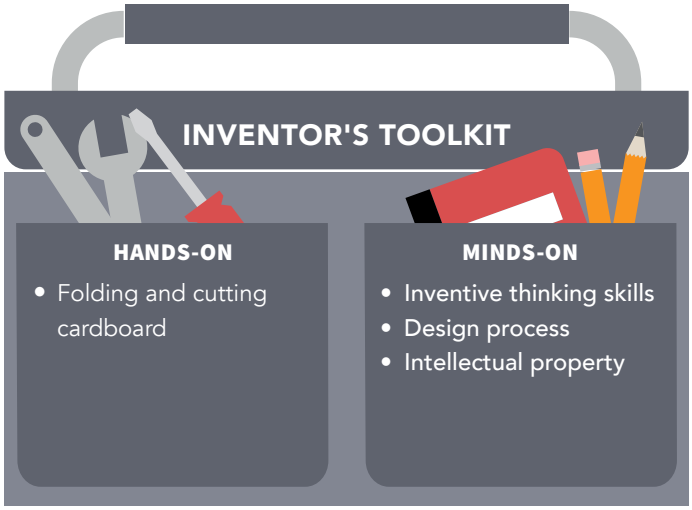
**Iteration (n):** A version of a design in a series of designs.

**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

- Get your JV InvenTeams Guide
- 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

MEETING 1

## 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.

Early prototypes of the Polaroid camera from the MIT Museum collection

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.

### STUDENT NOTE

**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.

## VIDEO NOTES

What are two helpful things you learned about working with cardboard from the video(s) you watched?

1.

2.

## BRAINSTORM

Brainstorming ideas before you build is one way to make your final product better. Use the graph paper in the back pages of this meeting to brainstorm two different cell phone holders.

# DESIGN A CELL PHONE STAND

1. Do you ever get annoyed by phones not being able to stand up on their own? Inventors think outside of the box and often 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 and 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, you can check out **Josh Ramos' Cardboard Phone Stand.**

5. When you're finished, respond to these Follow-Up Questions

   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. Share your design with another student.

7. How would you incorporate your comments and theirs in your next design? Describe this next design **iteration** in words or pictures.

8. During the JV InvenTeams initiative, you will learn about new tools and materials through invention activities like this one. You will think of iterations to improve or change your designs after successfully meeting these challenges.

## 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 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** (watch first 9 min)

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/or healthier.

MEETING 1

photo credit: MIT 2.009

**SAFETY**

**Continue watching Josh Ramos' Cardboard Videos to develop your skills when working with cardboard before doing the activity.**

### VIDEO NOTES

Write down some thoughts you have about the videos here:

1. General thoughts:

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

3. What failure have you learned the most from?

## RESEARCH AN INVENTION

1. 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. 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. 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.

4. Take a few minutes to research the product you identified.

5. How can this product continue to improve?

6. What information can you gather from the technical drawings?

7. Why are detailed images such an important part of a **patent**?

**PATENT PROFILE**

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

## DISCUSS IMPROVEMENTS TO AN INVENTION

1. You will work in a small group to brainstorm how you could improve one product or process you use during a typical day. You will respond to the following prompts in your guide:

   - 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?

2. You will learn to carefully observe the world around you in search of problems that can be addressed with a techno-logical solution.

MEETING 1

### PRODUCT NOTES

What are three things that don't work quite right in your daily life?

1.

2.

3.

How could you improve these things?

## 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.

### STUDENT NOTE

**Steps of the design process are:**

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

## WATCH VIDEOS ABOUT THE DESIGN PROCESS

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

2. Take time to outline the design process in your guide.

## SET RULES AND DEVELOP TEAMS

1. JV InvenTeams 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. Most of the projects require working in small teams. 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.**

## SELF-ASSESSMENT

Turn in your completed self-assessment as exit slip when you leave.

## INDICATORS OF A SUCCESSFUL MEETING

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

## FOUR CORNERS GAME

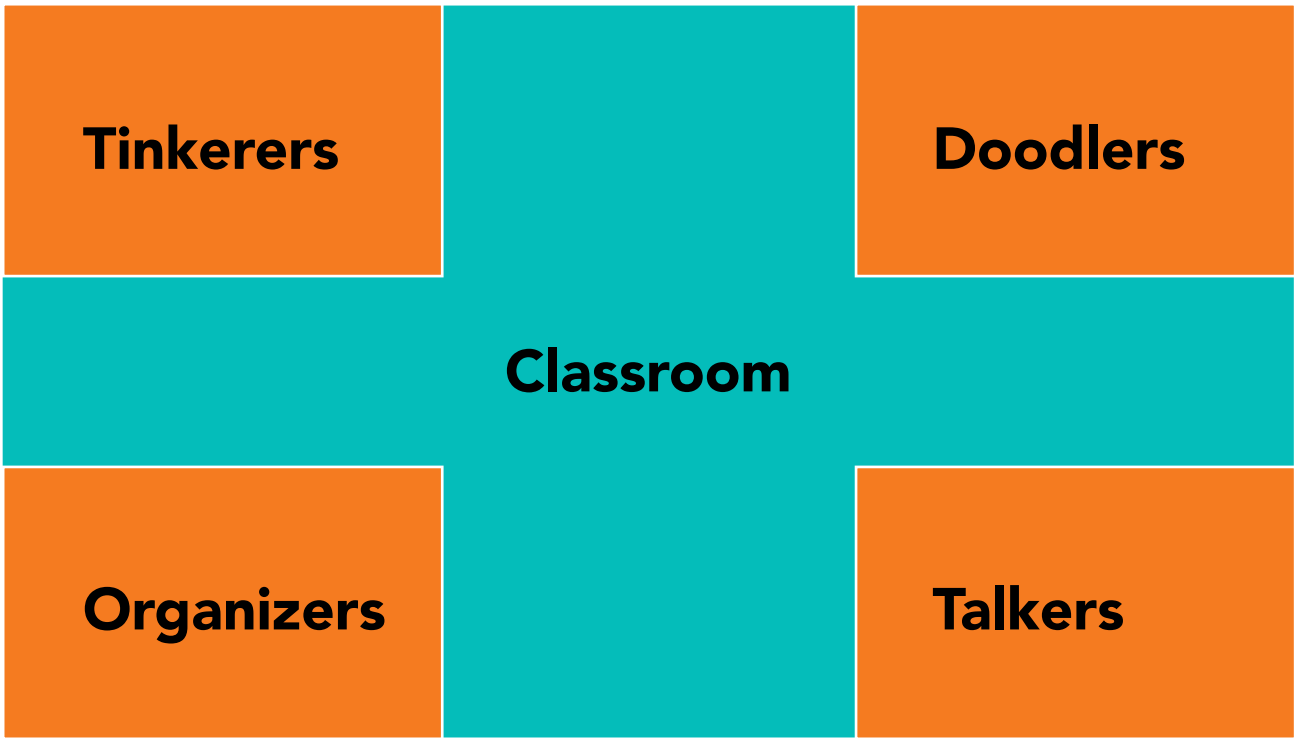
Teams of inventors include people with different interests and skills. Think about your own interests and skills; this will help your instructor organize the class into diverse teams. Draw a line from each type of team member on the left to the best-matching description on the right.

The corners of your classroom will be marked with the four types of team members. Which corner best matches your interests and skills?

Go to your respective corner, based on your "sounds most like me" description. The corners will have an equal number of students in an ideal world. If they don't, equal numbers are needed in order to make well-balanced teams. If you're in the larger group(s), look at your "sounds almost like me" description and compare with the corners needing students. 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 |

Count off within your corners once each has a nearly equal number of students. Finally, all 1s, 2s, 3s, and 4s will come together to form **invention** teams. These teams will come into action when you start team designing.



# SHOE SOLES
## MEETING 2: BIOMECHANICS & BIOMIMICRY

### KEY TERMS

**Aesthetic (adj):** Relating to the visual or artistic appeal of something.

**Biomechanics (n):** The study of mechanics relating to the structure and function of living things.

**Biomimicry (n):** Using nature as inspiration to solve human problems.

**Center of gravity (n):** The middle of an object's weight distribution.

**Force (n):** A push, pull, or twist.

**Friction (n):** The resistance that one object encounters when in contact with another.

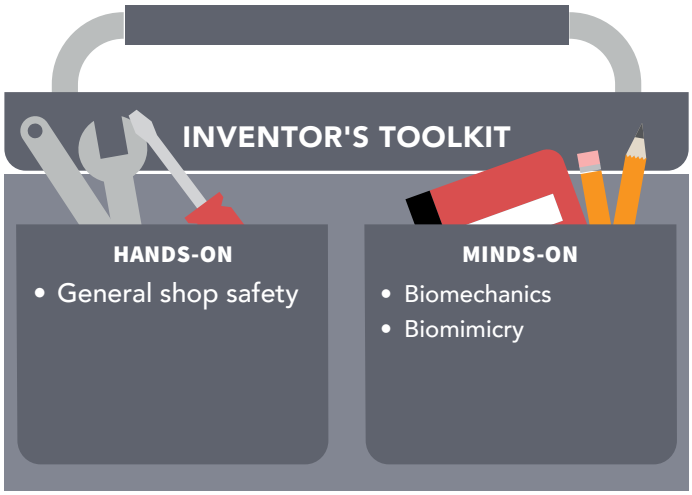
**Gait (n):** The pattern of movement of the legs during walking or running.

**Mass (n):** A measurement of the amount of matter something contains.

**Physiology (n):** The way in which a living thing or body part functions.

**Terrain (n):** Physical features of specific land.

**Traction (n):** A type of force describing how well something grips onto something else.




### Tools & Electronics

- Writing utensils
- Projector and computer to show video(s)

### Materials

- Student guides
- Shop safety rules
- Images of a variety of shoe soles
- Images of various animals and plants
- Self-Assessments

### Procedure

- Introduction to Shop Safety
- Introduction to **Biomechanics**
- The Science of Movement
- Investigate Foot **Physiology**
- Gihan on **Biomechanics**
- Examine Your Shoes
- Introduction to **Biomimicry**
- Begin the Shoe Sole Project (Research)
- Self-Assessment

## INTRODUCTION TO SHOP SAFETY

1. You may be using hand tools such as saws and screw drivers and basic power tools such as drills and rotary tools. To stay safe, you must use tools in the way they were designed to be used. Watch **General Shop Safety.**

**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.**

## INTRODUCTION TO BIOMECHANICS

1. Do you like to run or play a sport? Have you ever thought about the complex processes that allow you to move in the right way?

2. You will watch a compelling video that centers on the **biomechanics** of Olympic sprinter, Usain Bolt. Mechanical engineers Dr. Anette Hosoi (MIT) and Samuel Hamner (Stanford University) examine how Usain Bolt's physical structure affects his running ability.


3. Watch **The Biomechanics of Usain Bolt** (5:24). Answer these questions in their guides:

   - What did you learn about **biomechanics** from the clip?
   - Why is Usain Bolt not expected to run as fast as he does?
   - How does **force** come into play with movement?
   - How does the stance phase of running differ from the flight phase?
   - Why is the design of a shoe important in determining the performance capabilities of the athlete?

## THE SCIENCE OF MOVEMENT

1. Underline the important parts of the following reading.

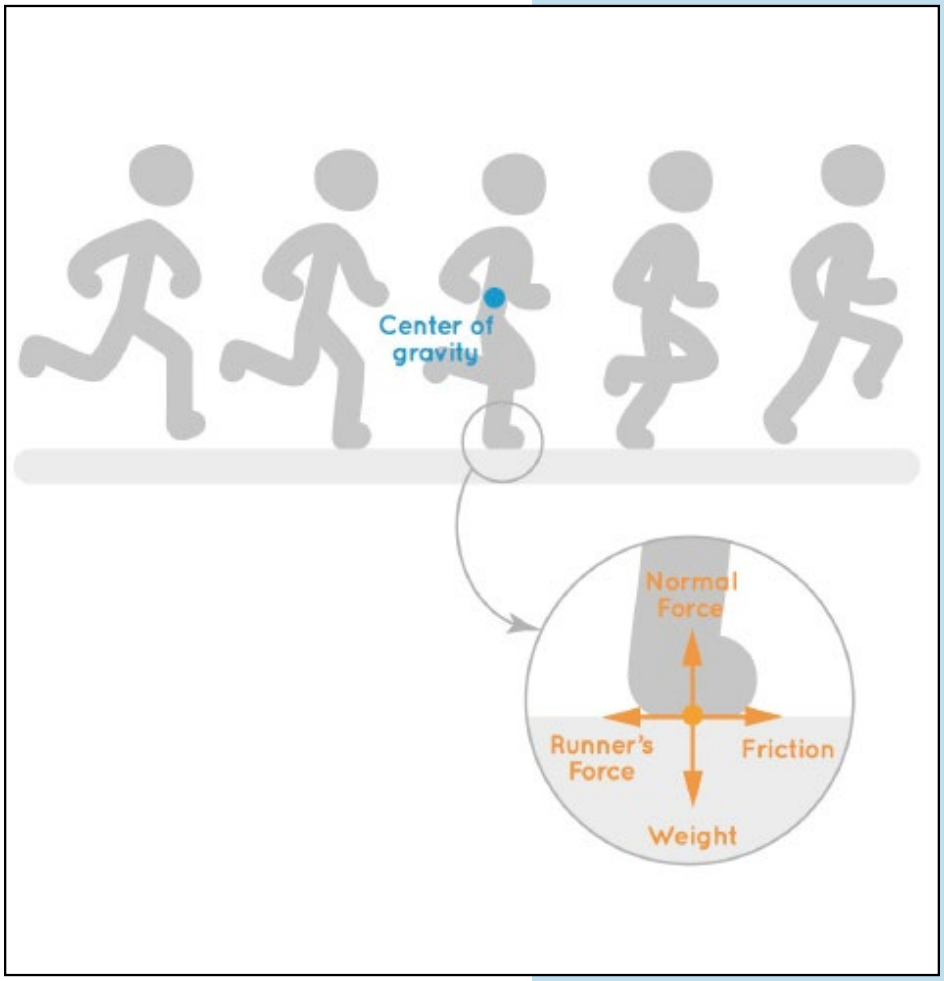
2. After reading, talk with a partner about what you learned.

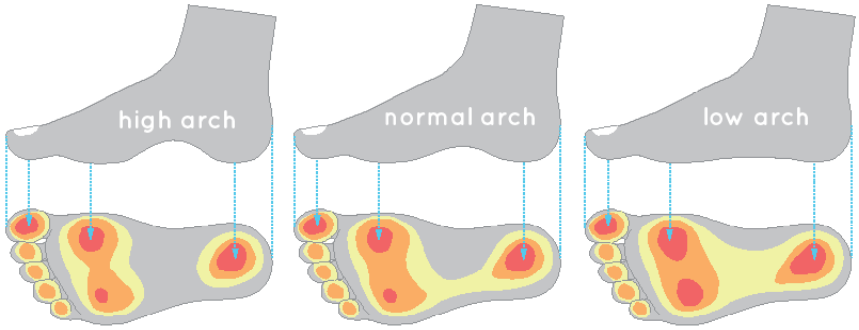
Have you ever wondered why athletic shoe stores have so many options? It is because the requirements for various sports are different. Engineers and designers need to identify the needs of the user and understand their body and movements in order to know how to make a functional shoe sole for each activity. Will the user be walking, running, cutting from left to right with a soccer ball, or needing **traction** for climbing rocky, snowy mountains? What unique physical attributes does the user have? How will these attributes affect their performance?

In the case of Usain Bolt, engineer Samuel Hamner analyzed the physical characteristics of Bolt's body. He also examined how various parts of Bolt's body work together when he is running.

Running is an impact sport. It is an act that exerts a **force** against the ground. The **force** against the ground provides **traction** and allows a body to "bounce" forward. The relationship between **force** and running speed is dependent on body weight, **gait**, stride mechanics and functionality of biological tissues such as bone, ligament, tendon, skin, and muscle. Humans have a **center of gravity**, which changes as humans walk, move, sit, and stand. Sprinters, while running, have a low **center of gravity** and the upper body is leaning forward slightly. Joggers or long distance runners tend to carry a high **center of gravity** and the upper body is vertical. The vertical **force** applied to the ground increases as the **center of gravity** moves from low to high, and as the vertical **force** increases, running speeds decrease.

The diagram shows the interplay of body weight (**mass**), **friction**, and **force**. You can begin to see the importance of designing a shoe that will provide the correct amount of **friction** (to help push off the ground), and support (to help land on the correct part of your foot and avoid injury).






## INVESTIGATE FOOT PHYSIOLOGY

1. Use the prompts below to investigate your own foot **physiology** with a partner.
   - What parts of your foot hit the ground when you move? Go outside and observe a partner running if you have time.
   - Remove your shoe/sock and examine your foot. Do you think you have a flat foot, normal arch, or high arch? How would this affect what type of shoe sole you need for walking?

## GIHAN ON BIOMECHANICS

1. Watch **Gihan Amarasiriwardena Discusses Shoe Design** (3:58) in which Gihan discusses the **biomechanics** of running at Fenway High School in Boston, MA. Gihan is a footwear and clothing designer who graduated from MIT.

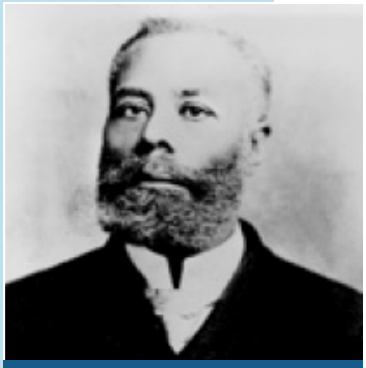
2. Now that you know more about the anatomy and **biomechanics** of the foot, you will find out what shoe companies do to design shoes that fit the needs of their users.

3. Investigate running shoe design by visiting websites like **NIKE**, **New Balance** and **Reebok**. Do you see running shoe designs that help people run more naturally?

**STUDENT NOTE**

**Extend the Learning**

Find out more on runner's **gait** here: **Understanding Running Gait.**



source: www.wikipedia.org

**INVENTOR SPOTLIGHT**

**Elijah McCoy was an African-American inventor from Massachusetts (1844-1929) who made improvements to the rubber shoe heel. Check out his fascinating story by clicking on History: Elijah McCoy.**

**Explore his rubber heel design patent from 1925 here: History: Design for a Rubber Heel.**

MEETING 2

## EXAMINE YOUR SHOES

1. You must make many observations to determine the ideal shoe sole for a given sport. These include:
   - Movements required by the sport
   - Physical body attributes of user
   - Characteristics of user's foot
   - **Terrain** of the intended activity
2. Inventors and designers often examine products already on the market before creating a new product.
3. Why do you think the shoes you are wearing were designed?
   - Intended use
   - Intended **terrain** and weather conditions
   - Comfort features
   - **Traction** features
   - **Aesthetic** design
   - Materials selection
4. Now observe another classmate's shoes. Discuss the following:
   - What activity do you think the shoes were intended for?
   - What do you notice about the outsole (bottom) of the shoes?
   - Does the outsole have ridges, grooves, or treads? Why?
   - Does the outsole have patterns or shapes? Why?
   - Do you use this shoe as it was intended to be used? Why/why not?
   - What do you notice about the shoe that makes you curious?

**INVENTOR SPOTLIGHT**

**Dutch designer Marieka Ratsma, along with American architect Kostika Spaho, created an innovative shoe using a 3D printer, inspired by a bird's hollow skull. Not only are the shoes unique looking, but they also use far less material than a typical high heel shoe, while still being structurally supportive. Check them out here: Inventor Spotlight: Biomimicry in Fashion.**

Source: www.dezeen.com

**STUDENT NOTE**

**Pre-chart**

Before you complete the chart in your guides, look at a sample shoe with the rest of the class.

5. Working in pairs, use the following chart to list problems with the designs of the shoes you just examined, and then list possible examined, and then possible solutions. Inspiration for the possible solutions may come from combining positive attributes of multiple shoes or substituting materials that are used in making the shoes.

| Shoe | Problem | Possible Solution | Inspiration |
|---|---|---|---|
| | | | |

## INTRODUCTION TO BIOMIMICRY

1. Inventors always look for problems to solve. Inspiration can come from many places. Sometimes, inventors look to nature for inspiration and mimic nature's solutions through engineering. This is called **biomimicry**. **Biomimicry** is an example of transgressive thinking: applying knowledge from one area flexibly to another.

2. Watch **Biomimicry in Action** (17:39), a TED talk featuring Dr. Janine M. Benyus, a leader in the emerging field of **biomimicry**.

3. Reflect on the video using the following prompts:

   - What does this talk have to do with your focus on shoe soles?
   - How can nature influence design? What can we learn from animals, plants and insects?
   - Could any of the examples from nature that Dr. Benyus mentioned inspire your shoe sole designs?
   - What animal, plant or insect inspires and informs the design of athletic shoes?

**EXTEND THE LEARNING**

**Visit AskNature, a project of the Biomimicry 3.8 Institute.**

**In the "how does nature..." search box at the upper center of the homepage, put in words associated with athletic shoes.**

source: fbei.wordpress.com

MEETING 2

## BEGIN THE SHOE SOLE PROJECT (RESEARCH)

1. You have completed the first few 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., shoe sole that functions for a specific purpose), researching, brainstorming and formulating ideas.

2. You will move from thinking about the problem to doing something that solves the problem. You will work in teams to design and build a prototype for a shoe sole. You will start with researching and interviewing prospective users. Then, you will sketch your design, make 3D clay models, and present your ideas to the team. Your team will make a mold of the clay model and create a prototype using rubber compounds.

3. Your educator will assign you to a team based on your choices in the Four Corners game from the last meeting.

4. Your team will design a shoe sole for a specific athletic activity. Possible activities include: basketball, soccer, dancing, football, and skateboarding. Choose an athletic activity as a team and record it below (if your team is having trouble coming to an agreement, try voting).

My team's athletic activity is:

What are features of existing shoe soles that you like?

What are some problems you foresee with these shoes soles?

**INVENTION SPOTLIGHT**

**NIKE created a running shoe inspired by mountain goat hoof traction. Check out their patent by clicking on Invention Spotlight: NIKE, Goat Hooves, and Shoes.**

Source: www.nike.com

What would you do to modify these shoe soles?

How could you include some inspiration from nature?

What are some questions you might ask a person who participates in your activity to find out what problems they have with their current shoes?

5. Divide the following research and interview tasks among your team. Teams were created based upon varied interests and skills, so think about your strengths as you view the list.
    - Search for images and videos that focus on the foot impact involved during your athletic activity.
    - Research the **terrain** and weather specific to your athletic activity (loose rocks, grass, snow, cement, etc.).
    - Interview people who participate in your athletic activity about the problems they have with their shoes. Propose some of your solutions and get their feedback.
    - Take pictures, make sketches, or create short videos of an athlete doing your activity.
6. Take notes using the blank pages on the back of your guide. You will be asked to share your findings during the next meeting!

## EXTEND THE LEARNING

**The biomimetic robotics lab at MIT develops robots inspired by animals. Robots include:**

- **Cheetah-inspired quadruped**
- **Cockroach-inspired hexapod**
- **Gecko-inspired climbing robot**

**Explore these robots in action at:**

**College Connection: MIT Biomimetic Robotics Lab Videos.**

photo credit: Charl Durand | Unspalsh.com

# SHOE SOLES
## MEETING 3: SKETCH & DESIGN

### KEY TERMS

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

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

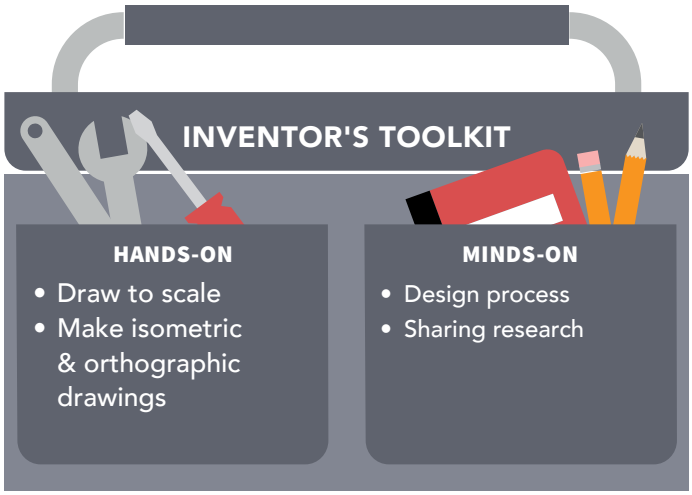
**Lug (n):** A ridge that helps to provide traction as on a tire or the sole of a shoe.

**Negative space (n):** The space around and between an object.

**Orthographic drawing (n):** A drawing showing all views of an object - top, side, and front.

**Outsole (n):** The outermost layer of a shoe.

**Scale (n):** The ratio of an object in a drawing to the size of the true object.




### Tools

- Writing utensils
- Rulers
- Computer and projector to show video

### Materials & Shop Supplies

- Student Guides
- Self-Assessments
- Images of shoe soles specific to each team's athletic activity

### Procedure

- Triathlete Shoe Video and Discussion
- Share Research
- Investigate Existing Shoe Soles
- Practice Drawing to Scale
- Draw Your Shoe Sole
- Introduction to **Isometric Drawing**
- Introduction to **Orthographic Drawing**
- Continue the Shoe Sole Project (Design)
- Self-Assessment

MEETING 3

## TRIATHLETE SHOE VIDEO AND DISCUSSION

1. Watch **Triathlete Shoe Video** (5:49), which showcases Chi-An Wang, a former undergraduate at MIT. As part of her undergraduate degree in Mechanical Engineering, Wang worked closely with shoe manufacturer, New Balance, to design and test a new shoe for triathletes.

2. Reflect on the video using the following prompts:

   - Identify Problem: What is the real-world problem that Wang identified?

   - Research: What type of research did Wang use to get answers? Why was it important to find out what the user wants?

   - Design Prototype: How did Wang's prototype address the needs of the potential users? What role did making and testing a prototype play in determining the final version of the shoe?

   - How did failure play a key role in making her shoe better?

   - What did Wang's advisor mean when he said, "consumers don't want to buy a product; they want to solve a problem"?

### EXTEND THE LEARNING

**Traditionally, running shoes are made with a cushioned outsole to help absorb shock and prevent injury.**

**Manufacturers are beginning to make minimalist or low-cushioned running shoes, which allow runners to strike first with the ball (front) of their foot instead of the heel. This results in less reaction force and may help prevent injury. Visit The Physics of Running Bared to read more about this debate.**

photo credit: Sage Friedman | Unspalsh.com

## SHARE RESEARCH

1. Share research on your athletic shoe soles with your team. Compile everyone's research and record major findings in your guide. Include what you learned last meeting about force, friction, tread, foot structure, biomechanics and biomimicry.

2. Your team can organize its thoughts using this list:

   - What activity is the shoe designed for?
   - What type of terrain? (e.g., dirt, grass, rocks, wet)
   - What type of movement is involved? (running, climbing, etc.)
   - How will the sole be shaped? (placement of **lugs** and **negative space**)
   - What materials will I need for the sole?
   - What part is inspired by nature?

3. Use the information on the next two pages to investigate existing shoe soles and to sketch your first design for your athletic shoe sole.

## INVESTIGATE EXISTING SHOE SOLES

Columbia Drainslip™ II

**INTENDED USE:**
Walking in the rain

**TERRAIN:** Wet ground

**MOVEMENTS:** Forward motion through puddles

**SOLE DESIGN AND MATERIALS:** Triangular **lugs** to allow for water drainage; more detailed pattern on toes and heels to provide additional friction at point of contact

Columbia Peakfreak™ Enduro OutDry

**INTENDED USE:**
Hiking

**TERRAIN:** Rugged trails

**MOVEMENTS:** Up and down, side-to-side, over hills with loose gravel

**SOLE DESIGN AND MATERIALS:** Multi-directional traction **lugs** and heel crash zone point of contact

Columbia Bugaboot™ Slip

**INTENDED USE:**
Winter boot

**TERRAIN:** Snow and ice

**MOVEMENTS:** Forward through uneven ground, up and down snowy mounds

**SOLE DESIGN AND MATERIALS:** Rubber compound with winter-specific lug tread pattern for traction in snow

Reebok Zigkick Hoops

**INTENDED USE:**
Basketball

**TERRAIN:** Hard wooden court

**MOVEMENTS:** Jumping, pivoting, sprinting

**SOLE DESIGN AND MATERIALS:** Cushions at the point of impact; stability throughout the midfoot, and responsiveness in the front of the foot; high-abrasion rubber **outsole** for durability

## Fill in the blanks next to the shoe sole images below.

New Balance MSD400

**INTENDED USE:**
Track spike

**TERRAIN:**

**MOVEMENTS:**

**SOLE DESIGN AND MATERIALS:**

Adidas® Seeley

**INTENDED USE:**
Skateboarding

**TERRAIN:**

**MOVEMENTS:**

**SOLE DESIGN AND MATERIALS:**

Capezio Kids Daisy

**INTENDED USE:**

**TERRAIN:**

**MOVEMENTS:**

**SOLE DESIGN AND MATERIALS:**

**INTENDED USE:**

**TERRAIN:**

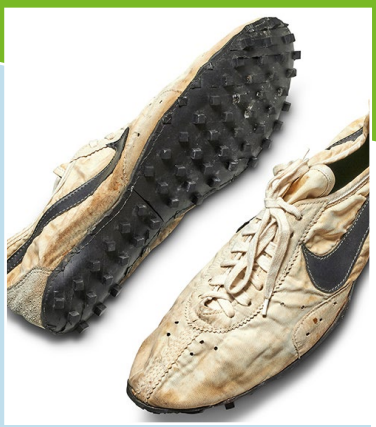
**MOVEMENTS:**

**SOLE DESIGN AND MATERIALS:**

Simple First Sketch of Shoe Sole for Team's Activity

## EXTEND THE LEARNING

**Did you know that running shoes and breakfast have a connection? Read about Bill Bowerman's invention of "waffle-soles" by clicking on History: Waffle Shoes**



source: robbreport.com

## PRACTICE DRAWING TO SCALE

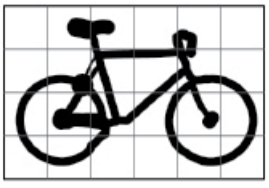
1. A scale drawing is a drawing that shows an object with accurate sizes except they have all been reduced or enlarged by a certain amount.

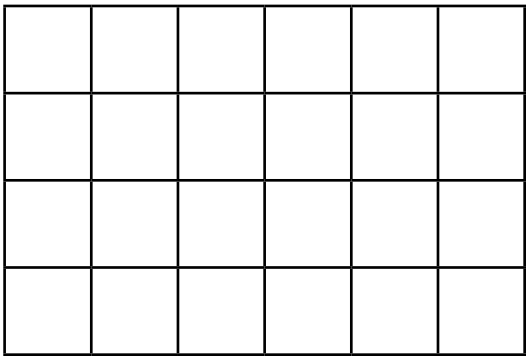
2. Engineers and architects make drawings to scale. They can then build models to scale from their drawings. Drawings of larger objects, such as machines and buildings, are scaled down to fit on paper. However, drawings of tiny objects like electronic parts are scaled up so that hey can be easily seen.

3. If a drawing has a scale of "1:10", anything drawn with the size of "1" would have an actual size of "10" in the real world. A measurement of 1 inch on the drawing would be 10 inches on the real object. As you can see, drawing to scale involves some mathematics.

4. Practice making an object larger using the outline below:

Drawing to **Scale**





MEETING 3

## DRAW YOUR SHOE SOLE

1. Draw an outline of your shoe sole on the graph paper. Your drawing should be **scaled** down by half, which is a 1:2 **scale**.

2. How can you calculate 1:2 **scale**?

   - Use a **Shoe Size Conversion Chart** (on next page) to determine shoe size in inches or centimeters.
   - Divide the measurement in half to figure out how large the **scaled** drawing should be.

3. Use rulers to mark your graph paper with your measurements. Remember to mark length and width.

4. Label your drawing with your name, date, and **scale**.

## INTRODUCTION TO ISOMETRIC DRAWING

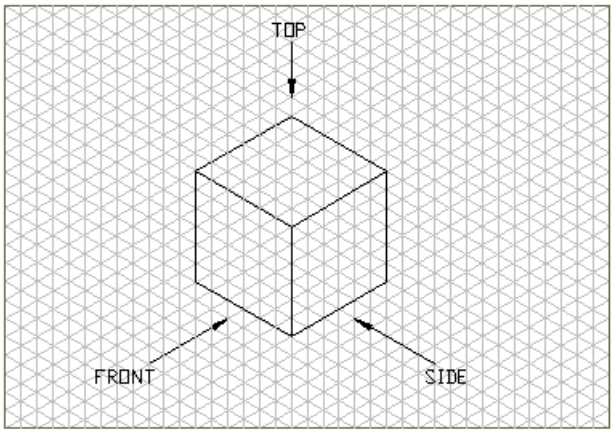
1. Do you like to draw?

2. Most sketches of 3D objects show just one view of the object, like the front view.

3. Engineers and architects use many different techniques to represent their 3D designs on paper. These drawings need to be incredibly accurate so anyone could build their project with the correct measurements.

4. "Isometric" comes from the Greek for "equal measure." An **isometric drawing** is a 3D drawing of an object, incorporating all three views (front, side, top) in one drawing.

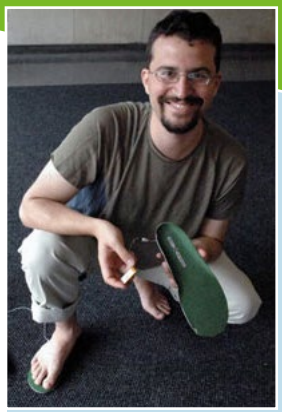
5. Review this **isometric drawing** of a cube.




**STUDENT SPOTLIGHT**

**Erez Lieberman, winner of the 2010 Lemelson-MIT Student Prize, invented the iShoe, an intelligent shoe insole that provides valuable information regarding a person's sense of balance.**

**Lieberman was even featured on CNN: College Connection: iShoe**



source: www.mit.edu

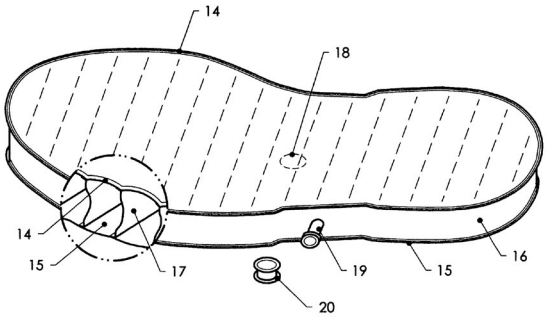
| Women's Shoe Size (US) | In | Cm |
|---|---|---|
| 4 | 8.1875 | 20.8 |
| 4.5 | 8.375 | 21.3 |
| 5 | 8.5 | 21.6 |
| 5.5 | 8.75 | 22.2 |
| 6 | 8.875 | 22.5 |
| 6.5 | 9.0625 | 23 |
| 7 | 9.25 | 23.5 |
| 7.5 | 9.375 | 23.8 |
| 8 | 9.5 | 24.1 |
| 8.5 | 9.6875 | 24.6 |
| 9 | 9.875 | 25.1 |
| 9.5 | 10 | 25.4 |
| 10 | 10.1875 | 25.9 |
| 10.5 | 10.3125 | 26.2 |
| 11 | 10.5 | 26.7 |
| 11.5 | 10.6875 | 27.1 |
| 12 | 10.875 | 27.6 |

| Men's Shoe Size (US) | In | Cm |
|---|---|---|
| 6 | 9.25 | 23.5 |
| 6.5 | 9.5 | 24.1 |
| 7 | 9.625 | 24.4 |
| 7.5 | 9.75 | 24.8 |
| 8 | 9.9375 | 25.4 |
| 8.5 | 10.125 | 25.7 |
| 9 | 10.25 | 26 |
| 9.5 | 10.4375 | 26.7 |
| 10 | 10.5625 | 27 |
| 10.5 | 10.75 | 27.3 |
| 11 | 10.9375 | 27.9 |
| 11.5 | 11.125 | 28.3 |
| 12 | 11.25 | 28.6 |
| 13 | 11.5625 | 29.4 |
| 14 | 11.875 | 30.2 |
| 15 | 12.1875 | 31 |
| 16 | 12.5 | 31.8 |

1. Draw an isometric outline of your shoe sole. You can add to the scaled shoe sole you already drew. It's a little trickier than a cube, and it might look something like this:

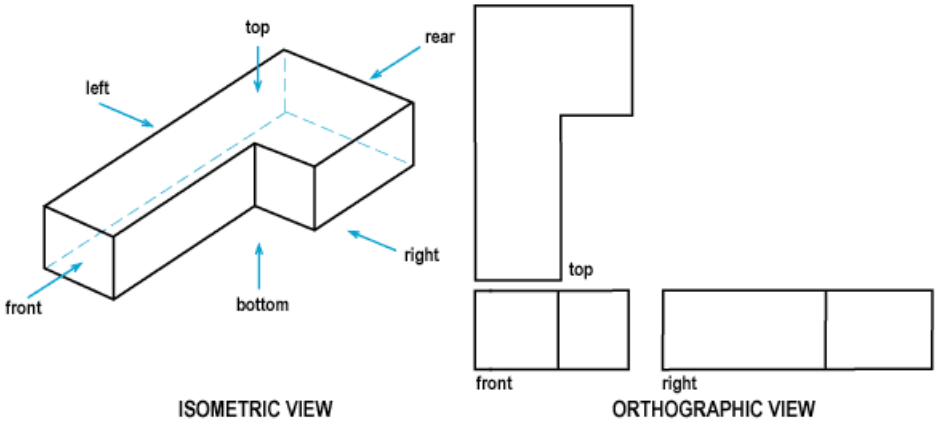
## INTRODUCTION TO ORTHOGRAPHIC DRAWING

1. **Orthographic drawings** take each of the views - top, front, side - and put them into separate two-dimensional drawings next to each another. This makes it easier to see the complete view of each component.



Google Patent US 7523565 B1

2. Review the example of **isometric drawing** (below) on the left with its orthographic representation on the right.



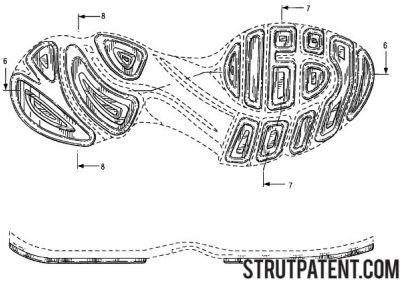
ISOMETRIC VIEW ORTHOGRAPHIC VIEW

3. Add orthographic views of their shoe sole in your guide. Focus on the top and side views.

4. The top view is where you will draw the design of the treads, and the side view is where you will show the thickness of various sections.

## CONTINUE THE SHOE SOLE PROJECT (DESIGN)

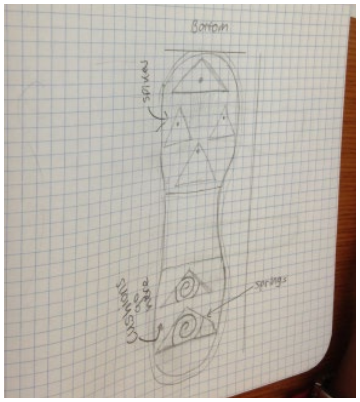
1. Practice drawing to **scale** and making isometric and **orthographic drawings**.



MEETING 3

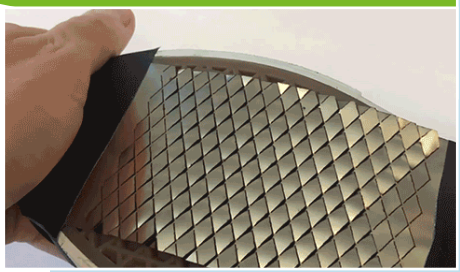
2. Check out the **Howtoons Visual Communication Guide** for some guidance on improving your sketches.

3. Use the rest of the meeting to begin designing the shoe sole for your team's athletic activity. You should fill in your final outlines - top and side views - with your choice of design features. You may need to do more than one drawing to convey the design elements the way you envision them.



**INVENTION SPOTLIGHT**

**Researchers from MIT and Harvard University have developed a new way to avoid slipping on dangerous surfaces. They were inspired by kirigami, the Japanese art of intricately cutting and folding paper, to invent shoes soles with more traction. Their research showed that using a pattern of inward curves in metal or plastic had the best results. Their next steps are figuring out how to attach the surfaces on shoes. Learn more about kirigami here: Kirigami Coated Shoes**



source: MIT News

# SHOE SOLES
## MEETING 4: SCULPT CLAY MODELS

### KEY TERMS

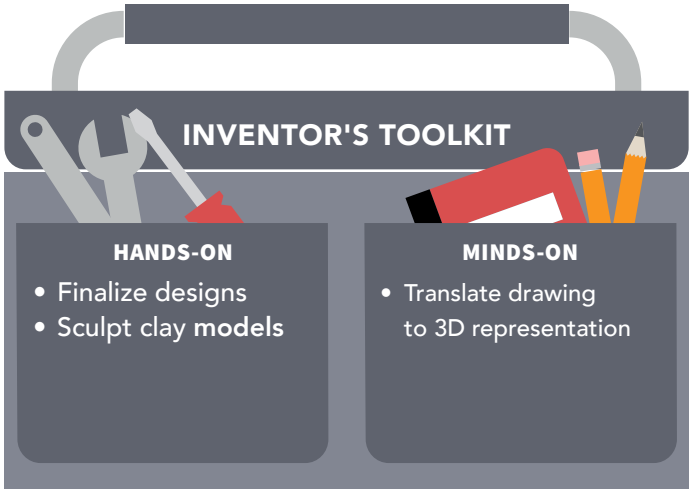
**Cast (v):** To pour a liquid material into a mold, and then let it harden.

**Model (n):** A 3D version of a proposed structure or thing.

**Mold (n):** A hollow container used to give shape to liquid material when it hardens.

**Pattern (n):** A form or model to be used for imitation.

**Pitch (v):** To make a bid to get a contract or other business.




### Tools & Electronics

- Writing utensils
- Clay sculpting tools
- Rulers
- Computer and projector to show video

### Materials & Shop Supplies

- Student Guides
- One-pound block of **modeling** clay per student
- Wax paper for protecting tables
- Self-Assessments

### Procedure

- Finalize Shoe Sole Designs
- Sculpt Clay **Models**
- Select **Model** for Prototype
- Self-Assessment

**INVENTION SPOTLIGHT**

**Take a look at the awesome Adidas® Springblade running shoe, which has a very unique pattern and use of materials on the outsole!**
**Springblade**


courtesy: www.adidas.com

MEETING 4

## FINALIZE SHOE SOLE DESIGNS

1. Continue drawing designs from the previous meeting.

2. Use the graph paper for your final drawing. Your final drawing must include:

   - Name and scale on top
   - Two views: top and side
   - Important dimensions
   - Labels for parts: lugs, negative space, etc.
   - At least one part inspired by nature

## SCULPT CLAY MODELS

1. Once you have finished your final design, you will carve your design out of clay. You will use this clay model to make your **mold**, or pattern.

2. Your final design should be full-scale, so about the size of your foot.


### STUDENT NOTE

**Before Sculpting**

It is easier to carve out of your clay than add pieces onto it.

A pencil or other pointed tool will help make fine lines and grooves.

### STUDENT NOTE

**After Sculpting**

Be sure to find a safe place to store the clay models.

### INVENTION SPOTLIGHT

**In the early spring of 2020, COVID-19 swiftly became a global pandemic, infecting millions of people worldwide. Researchers discovered that the virus could live for days on many surfaces, including shoe soles. This posed a risk for hospital workers who could potentially carry the virus from hospital room to hospital room or back to their homes. HealthySOLE invented a device that could get rid of the coronavirus by over 99.5%. Learn more about the device here:**

**UVC-Powered Shoe Sanitizer**

source: HealthySOLE PLUS

3. Follow these instructions to make your clay model:

- Cover your workspace with wax paper.
- Lay out 1/2 inch of clay to cover the outline of your shoe sole.
- Look at your side view drawing. Add clay to your sole to match the heights on your drawing.
- Use your design sketch for inspiration.
- Remove clay from all areas that will not be part of your shoe sole using carving tools.
- Make sure the clay comes out exactly as you want it to look, as you will use it to make your **mold**.
- Finish by smoothing out the clay with your fingers.
- Wash your hands and clean your workspace.

**TEAMWORK NOTE**

**Selecting a Model**

If your team is having trouble selecting a model, try letting everyone vote. Remember to be a positive contributor to your team.

## SELECT MODEL FOR PROTOTYPE

1. Share your model with your team. Only one design per team will be **molded**. Each person can "**pitch**" their design for selection to **cast** into the final prototype.

2. Your choice should be based on the design that most effectively and uniquely addresses the needs of your user. Everyone will get to participate in the **molding** process, regardless of the selection.

# SHOE SOLES
## MEETING 5: CAST CLAY MODELS

### KEY TERMS

**Casting (n):** Object made by pouring liquid into a mold.

**Cure (v):** To harden or set.

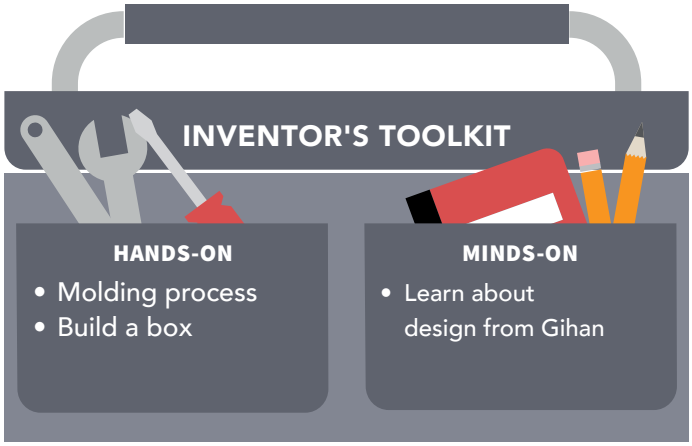
**Elastomeric (adj):** Having the elastic (stretchy) properties of natural rubber.

**Entrepreneur (n):** A person who organizes and operates a business, taking on financial risk to do so.

**VytaFlex® 30 (n):** A urethane rubber used in various processes such as architectural restoration, candlemaking, prototyping, and inventing. It is used to make a 3D physical representation of ideas to help determine commercial potential.

**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.**




### Tools & Electronics

- Writing utensils
- Paint stirrers or wooden craft sticks (1 for each team)
- 16-ounce plastic mixing containers (2 for each team)
- Rulers
- Computer and projector to show video

### Materials & Shop Supplies

- Student Guides
- Clay shoe models from the previous meeting
- **VytaFlex 30**, parts A and B
- Can of release agent
- Disposable aluminum pans with smooth bottom, 13” x 9” (1 for each team) OR cardboard boxes with aluminum foil
- Scrap cardboard
- Shipping tape
- Protective gloves (one pair for each student)
- Safety glasses (one pair for each student)
- Self-Assessments

### Procedure

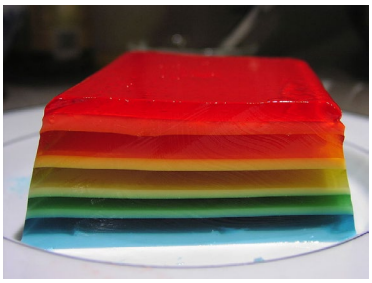
- Introduction to the Molding Process
- Prepare Molding Box
- Prepare **VytaFlex 30**
- **Cast** Clay Model
- Meet Gihan Amarasiriwardena
- Self-Assessment

MEETING 5

## INTRODUCTION TO THE MOLDING PROCESS

1. Have you experienced the molding process? Not the kind that grows on rotting food, but the kind that gives a shape to liquid when it hardens.

2. Read below to learn about some real-world uses of the molding process.



- Getting an impression of your teeth made at the dentist for a mouth guard is a real-world example of a mold.
- If you have ever made JELL-O®, then you have experienced a molding material. Making JELL-O involves mixing parts – powdered gelatin and water – to create a liquid. The liquid is then poured into molds of various shapes. When the liquid **cures**, it becomes a jiggly, fun food.
- Chocolate is also often molded. Stores carry themed chocolates wrapped in foil during the holidays. Have you ever thought about how these are made? It is likely that they are produced through the molding process. Check out the following video: **Callebaut Molded Chocolate**.

3. You will use a strong **elastomer** for your shoe sole. **VytaFlex 30**, a urethane compound, is both **elastomeric** and durable. It **cures** to mimic a rubber shoe sole.

4. Today, you will prepare a container for your mold, and then **cast** your clay model in **VytaFlex 30** to create the mold. You will use the mold as a **casting** to create your prototype in the next meeting.

**INVENTOR SPOTLIGHT**

**Do you like playing or watching basketball? Inventor Tinker Hatfield from Oregon is responsible for many of the designs of Air Jordan sneakers, one of the most widely recognized shoe products from the 1990s. Continue reading by clicking on Building a Shoe.**

## PREPARE MOLDING BOX

1. You will make a molding box out of cardboard lined with aluminum foil.

2. Keep a few things in mind while creating your box:


- The box must have a smooth bottom to work well.
- The box must be lined with smooth, heavy-duty aluminum foil.
- Use scrap cardboard and shipping tape to segment the molding box so there is just enough room for the clay model to fit inside.
- Add 1/2 inch to the length and width of the clay model. Make sure the box is 1 inch higher than the clay model.


## PREPARE VYTAFLEX 30

Make sure the work area is well ventilated. The **VytaFlex 30** can be mixed ahead of time for each team. The educator may mix each team's **VytaFlex 30** ahead of time, but if not, you'll do your own mixing. Below are the instructions for mixing the correct amount:

1. Each team will have one trial-size box of **VytaFlex 30** (parts A and B) to work with in this meeting and the next meeting. Approximately 2/3 will be used in this meeting and the remaining 1/3 in the next meeting. Use the 16-ounce measuring container to mark 7-ounces on one deli container as a guide. Pour 7 ounces of **VytaFlex 30**, part A, into a deli container.

2. Pour 7 ounces of **VytaFlex 30**, part B, into another 16-ounce container.

**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.**

**SUSTAINABLE SOLUTIONS**

**NIKE created a sneaker collection made from recycled waste in response to the growing demand for footwear created through sustainable practices. The shoe collection is called "Space Hippie," inspired by life on Mars where materials are hard to come by. The shoes are made from at least 25% recycled materials from the upper section to the outsole. Watch how NIKE is reducing their carbon footprint:**

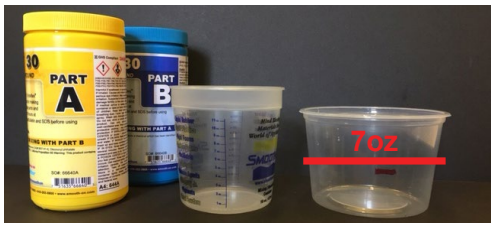
**Nike's Space Hippie**

source: nike.com

## CAST CLAY MODEL

1. Follow the instructions below:

- Put on protective gloves, eyewear and dust masks.
- Line tabletop with newspaper or plastic trashbags.
- Place the clay model, tread side up, in the molding box. Make sure it is firmly touching the bottom of the box so there is no room for the **VytaFlex 30** to seep underneath.




- Hand off the box with the clay model in it to your educator, who will spray the inside with a mold release agent.

- Prepare the **VytaFlex 30 by:**

a. Combine part A into part B in a deli container. Mix well with a craft stick.

b. Pour the mixture into the box to cover the model without letting it overflow.


c. Let your educator know if you need more **VytaFlex 30** to cover the clay model. Remember to only ask for what you need as supplies are limited.

- Let the mold **cure** (harden) for 24 hours.
- Clean up your space and make sure the **VytaFlex 30** containers are sealed.
- Throw unused **VytaFlex 30** into the trash. **DO NOT** pour it down the sink.

2. If your team finishes early, skip ahead and read the next section on Gihan Amarasiriwardena.

## MEET GIHAN AMARASIRIWARDENA

Gihan Amarasiriwardena began thinking like an inventor from a very young age. Gihan had a business taking care of lawns in his neighborhood from fifth grade through high school. He learned that he could save time and earn more money by doing two lawn chores simultaneously – mowing and trimming. Using parts from a local repair shop, Gihan added a trimmer assembly to a push mower.

source: www.gihan.amarasiriwardena.com

Gihan was always interested in building tree forts or simply creating things with construction sets. He learned to work with his hands so he could turn his ideas into reality. After Boy Scout camping trips, Gihan began to see a need for low-cost, high-performance outdoor gear and started designing on his own.

Gihan's early prototype was a waterproof fleece vest that he tested, redesigned, and re-tested until the vest design met his needs. The selection of the materials for the vest's inner layer took him from plastic trash bags to DuPont™Tyvek®, a lightweight waterproof and breathable barrier, popular in the construction industry.

Gihan graduated in 2011 from MIT with a degree in Chemical-Biological Engineering. While at MIT, he focused on engineering innovative footwear. Examples include customized racing shoes for a Paralympian at the Sports Technology Institute and customized racing shoes with added spikes for his own use.

1. You are going to watch two video clips of Gihan discussing invention and biomechanics.

2. Before beginning the videos, find and discuss definitions for the following words (write down any new definitions in your guide):

   - Traction
   - Pattern
   - Prototype
   - Orthotic

**EXTEND THE LEARNING**

**Gihan "hacked" products by taking pieces apart and adding better features. NIKE's CEO and head designer did the same thing with shoes as kids. Check it out: NIKE's Top Brass Hacked Their Own Shoes.**

### READING NOTES

Write down three new things you learned while reading about Gihan and exploring his website:

1.

2.

3.

- Strain Analysis
- 3D Printing
- Invention Process
- Podiatrist
- Innovative

3. Watch **Gihan Talks About Shoe Invention** (5:09), in which Gihan discusses his experience designing customized racing shoes, including a pair for a British Paralympian.

4. Today, Gihan has integrated his interest in performance wear with men's dress clothes. He co-founded a successful line of menswear called **Ministry of Supply**. Watch **Gihan as Entrepreneur** (6:42), in which Gihan explains the launch of his business and how he became interested in being an inventor.

5. Reflect on the videos using the prompts below:

   - How did Gihan inspire you?

   - How do you work in teams in your life to accomplish things?

   - What are two lessons you learned from Gihan in starting a successful business?

**EXTEND THE LEARNING**

**Read about Gihan's Ministry of Supply company in the New York Times:**

**Rolling Up Their Sleeves**

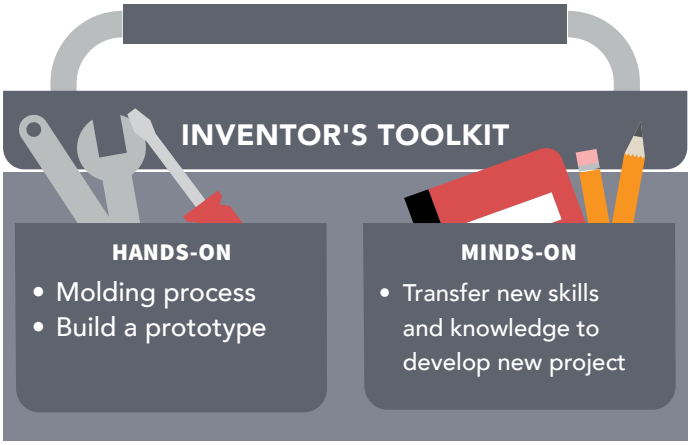
# SHOE SOLES
## MEETING 6: SHOE SOLE PROTOTYPE

### KEY TERMS

**Adaptive (adj):** Having the capacity for change.

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

**Prosthetics (n):** Artificial body parts.




## Tools & Electronics

- Paint stirrers
- 16-ounce plastic mixing containers (2 for each team)
- Writing utensils
- Computer and projector to show video

## Materials & Shop Supplies

- Student Guides
- VytaFlex 30, parts A and B
- Can of release agent
- Dye
- Plastic gloves (1 pair for each student)
- Safety glasses (1 for each student)
- Self-Assessment (page P13, copy one per student)

## Procedure

- Remove Clay Models
- Cast Shoe Sole Prototype
- Scott Portzline on Inventing
- Purposeful and Unique Inventions
- Brainstorm Invention Ideas
- Self-Assessment

MEETING 6

## REMOVE CLAY MODELS

1. Carefully remove your clay model from the box. Patience is important. There may be sticky spots or places where the VytaFlex 30 seeped too much. If there are sticky spots, use a clay tool to gently separate the clay from the mold. Use scissors to cut off extra pieces of VytaFlex, if it seeped.

2. The resulting VytaFlex shape is a mold that you will now use to create your prototype.

## CAST SHOE SOLE PROTOTYPE

1. Review the casting process below:

   - Put on protective gloves, eyewear and dusk masks.
   - Line tabletops with paper or plastic trash bags.
   - Hand off your box to the educator to spray release agent in your mold.
   - Prepare the VytaFlex:

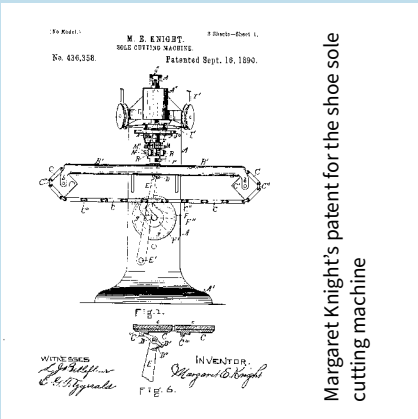
   a. (optional) Color your prototype by adding a few drops of dye to the part B container and mixing with a paint stirrer.

   b. Combine part A into part B in a deli container. Mix well with a craft stick.

   c. Pour the mixture into the mold without letting it overflow.

   - Let it cure for 24 hours.
   - Clean up your space.
   - Throw unused VytaFlex 30 in the trash. Do not pour it down a sink.

2. If you finish early, jump ahead to the reading on the next page.




Margaret Knight's patent for the shoe sole cutting machine

### INVENTOR SPOTLIGHT

**Margaret Knight (b.1838) was one of the most prolific female inventors in United States history. She had over 26 patents, which includes her famous machine for making paper bags. One of her notable inventions was a machine that could cut shoe soles. Learn more: Margaret Knight**

## SCOTT PORTZLINE ON INVENTING

Scott Portzline is currently the Footwear Design Director on the SOREL, Montrail, and Columbia brands, based in Portland, Oregon. When he was a kid, Scott was heavily influenced by his dad, who constantly built and fixed things, and his brother, who was an excellent drawer. These two family members taught him the basics of visualizing and making things. Scott always enjoyed drawing and later became obsessed with comics and anime. These interests took him on the pathway to becoming a product designer.

Scott Portzline's first footwear design experience was with ski boots and skates. He did projects for companies like RollerBlade and Ultrawheels while working as an industrial designer in Minneapolis. What struck Scott about his first footwear projects was the level of "intimacy" between the product and the user. The footwear needs to move with the foot and leg, can affect one's performance ability, and can become an extension of the user's personality. In 1995, Scott began an in-line skate project with NIKE, which eventually resulted in a design position within NIKE's newly-formed equipment division, focusing on NIKE Hockey. Scott spent nine years on the footwear side of the business during his eleven years at NIKE. He now works for Columbia Sportswear Company.

**INVENTION SPOTLIGHT**

**Scott Portzline has many footwear design patents. Find US D655483 S1 using the Google patent search. The patent contains 21 different views of the same shoe! Discuss why you think there are so many visuals.**

Scott's advice for future designers and inventors:

- Be creative: Draw every day and carry a sketchbook around with you. Get comfortable building things in 3D.
- Be passionate: The best design ideas get people EXCITED. Connect on an emotional level with your work, as well as functional.
- Be curious: Pay attention to how people interact with the things they use. Ask "Why?" Take stuff apart and figure out how it goes back together.
- Be flexible: Things never go completely as planned. Be okay with failure and learn from mistakes. Accept critique and criticism about your work in order to make it better.

If you could ask Scott one question pertaining to his work or the footwear industry, what would it be?

What classes in high school or college might help prepare you to be a designer?

Would you be interested in becoming a footwear designer? Why?

Is there a company or brand that you would like to work for? Why?

**INDUSTRY SPOTLIGHT**

**A large percentage of shoe manufacturing is accomplished less expensively overseas. New Balance prides itself on manufacturing their shoes in the United States, which also provides jobs for people living in the United States. Check out their vibrant production floor:**

**New Balance**

## INTRODUCTION TO PURPOSEFUL AND UNIQUE INVENTIONS

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, understanding the design process, biomechanics and biomimicry. You have gained hands-on skills such as drawing to scale, building models, molding and creating footwear. 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.**

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.

## PURPOSEFUL AND UNIQUE INVENTIONS

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

### Example 1

Hugh Herr directs the Biomechatronics Group at the MIT Media Lab. This group seeks to restore mobility to those who have experienced trauma or disease and develops technologies for human performance that go beyond what nature intended. Learn more by clicking on **MIT Biomechatronics Group**.

Watch PBS' **Titanium Chairs and Cheetah Legs** to learn about **adaptive** technologies, **prosthetics** and advanced wheelchairs used for athletes with amputations or physical disabilities.

### Discuss as a Class

- How are the technologies shown in the video similar? How are they different?
- How do the materials and design features of wheelchairs used in Paralympic tennis reflect the needs of the athletes who use them?
- **Adaptive** technologies are constantly changing. What do you think are the advantages and disadvantages for the Paralympic athletes who use them?

**INVENTOR SPOTLIGHT**

**Still trying to find really comfy shoes? Ronald Demon was an MIT student who invented an athletic shoe with cushioning that automatically adjusts to provide the maximum support and comfort to the user. Get the details here: Ronald Demon**

### Example 2

Rothy's is a company that serves as an excellent example of invention with service and purpose in mind. Click on **Rothy's** to learn more about how they transform eco-friendly materials into stylish, wear-everywhere products.

Can you think of any durable materials that could work for a low-cost shoe? What other populations might benefit from low-cost or specialized footwear? Record thoughts in the margin. Click on **Printable, Foldable Shoes Could Solve World's Footwear Shortage** to see an example of a low-cost, easy-to make shoe.

## Example 3

David Wallace, a professor in Mechanical Engineering at MIT, teaches a class on toy design. Students work in teams throughout one semester to develop a toy with a specific theme. They often use molding materials in the construction of their toys. Click on **Toy Projects** to get some inspiration from their toys and to see how molding can be used for a beneficial purpose. The specific theme in 2007 was inexpensive manufacturing in Brazil.

Can you think of a meaningful way to use molding other than footwear? Write down your ideas here:

## BRAINSTORM INVENTION IDEAS

1. Share your ideas with your team and work together to brainstorm new ones. Try to apply your hands-on and minds-on toolkit as you brainstorm. For example, how can the molding process be used to make something new? How can you create low-cost or adaptive footwear?
2. Use the Invention Challenge Brainstorm on the back of your guide to develop and track ideas.

### INVENTOR SPOTLIGHT

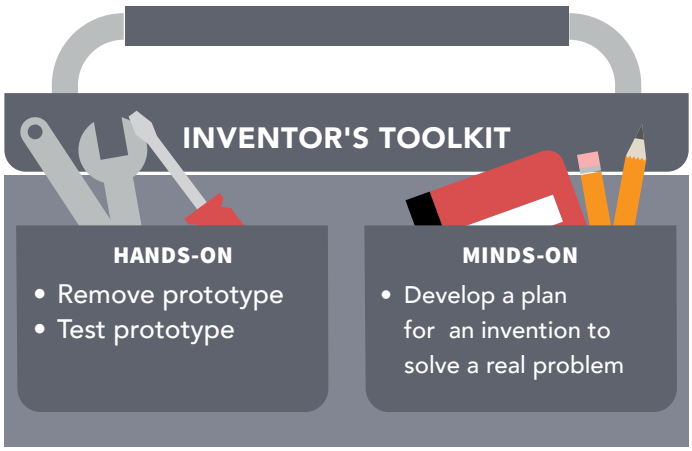
**Jason Mayden grew up in the Southside of Chicago during the Michael Jordan era and dreamed of somehow interacting with his hero. A creative and artistic kid, he decided to use design as his way of inspiring people and engaging with the world. While studying at Detroit's College for Creative Studies, his mind was set on interning for NIKE, specifically on his hero's Air Jordan brand. After three rejections, he finally landed an internship. His determination, creativity and skills led him to eventually become lead designer at NIKE's Air Jordan Brand. In 2018 he became CEO of Super Heroic, a line of affordable footwear for children that encourages them to be creative in their play. Learn more about Jason Mayden and his inspiring career path:**

**Jason Mayden's Super Heroic Line**

**How He Got There**

**2012 TedEx Talk**

# SHOE SOLES
## MEETING 7: TEST PROTOTYPES & INVENTION EXTENSION




### Tools & Electronics

- Writing utensils
- Computer and projector to show video

### Materials & Shop Supplies

- Student Guides
- Prototypes
- Flip-flop (1 for each team)
- Quick-cure epoxy
- Paint stirrers
- Newsprint
- Roll-on stamp pad ink (or finger paint)
- Self-Assessments

### Procedure

- Test Your Prototype
- Get Feedback
- Brainstorm Ideas for Unique and Purposeful Inventions
- Make a Plan
- Self-Assessment

Shoe soles made by 9th & 10th graders

## TEST YOUR PROTOTYPE

1. Carefully remove your prototype from its mold. Congratulations on your first prototype!

2. These shoe soles are in the prototype phase. Prototypes are often made out of different materials or made using a smaller scale than the final version.

3. It's time to test your prototype. Shoe designers typically test with users once the product is made to scale with the final materials. However, there is a lot of intermediate testing, often in a laboratory setting, to help guide designers.

4. Review the testing procedure below:

   - Wash the shoe sole in warm, soapy water to remove any remaining release spray. Dry it.
   - Cut a piece of cardboard slightly larger than the shoe sole.
   - Glue the shoe sole (side without treads) to one side of the cardboard.
   - Let the shoe sole dry for five minutes.
   - Lay the paper on a tabletop or on the floor.
   - Apply roll-on stamp ink evenly over the shoe sole thread.
   - Press the cardboard/shoe sole onto paper to make an imprint.
   - Complete the testing chart on the next page.

**HIGH SCHOOL CONNECTION**

**The 2013 St. Ursula Academy InvenTeam (Toledo, Ohio) invented a pill-dispensing organizational system for individuals having difficulty managing their medications. They used a molding process called vacuum molding to create some of their parts:**

**Vacuum Molding**

**Team's Activity:** _____

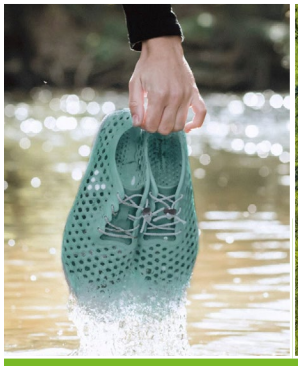
| Questions | Assessment |
|---|---|
| Look at the imprint on the paper. What parts of the shoe sole are hitting? Is this how it was intended? | |
| Does the shoe sole allow the user to move in the directions needed for the assigned activity? | |
| Does the shoe sole have an arch? How well does it support the foot for the intended activity? | |
| Observe the placement of lugs and negative space. Are the lugs adequate? Is more or less negative space needed? | |
| Would your shoe sole be appropriate for the terrain of your assigned activity? Explain. | |
| What are some recommendations for improvement? | |
| How would you design the rest of the shoe to go with the shoe sole? What materials would you use? | |

## GET FEEDBACK

1. Conference with another team to discuss their shoe sole prototypes.

2. Start by selecting a communications leader for your team. This person will present the team's intended activity for the sole and provide information pertaining to the terrain, and motion required by the activity.

3. Ask each other the same questions that you answered about your own design to get started. Remember, keep the feedback constructive and specific!



source: Vivobarefoot

### SUSTAINABLE SOLUTIONS

**Shoes made out of algae? Yes, that's right! Algae overgrowth in ponds and lakes is an increasingly big problem due to pollution from agricultural runoff water. A major algae explosion in China's Lake Taihu left several million people without safe drinking water. Vivobarefoot recognized a solution to the problem by collecting the algae and turning it into a rubbery material for shoes.**

**Read more: Shoes that Clean Lakes**

## INVENTION CHALLENGE

1. You began brainstorming ideas for the Invention Challenge in the last meeting. Today you will determine a need that can be realistically and successfully addressed among your team members.

2. This is not a project that will be completed from start to finish in the JV InvenTeams meetings. It is a project that can be planned and completed outside of meeting time.

3. You can apply for an InvenTeam grant to help fund the development of your idea. Potential materials that will be used do not need to fit into a specific budget.

4. You can research specific communities or regions to gather ideas using the **World Bank** website.

5. Record all of your research findings and ideas in your guide.

## BRAINSTORM SOLUTIONS

1. 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 to arrange the characteristics of what is challenging you to 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?)

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

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

4. 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?
   - 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?

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**!

**COLLEGE CONNECTION**

**Researchers at MIT discovered that a typical pair of running shoes has a pretty big carbon footprint. Most of the impact comes from carbon emissions generated by the manufacturing process. Read more and think about how you can create an environmentally friendly shoe: Footwear's Carbon Footprint**

## 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: _____
(the user)

_____

because: _____
(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 is: _____

## DRAW IT

Name: _____

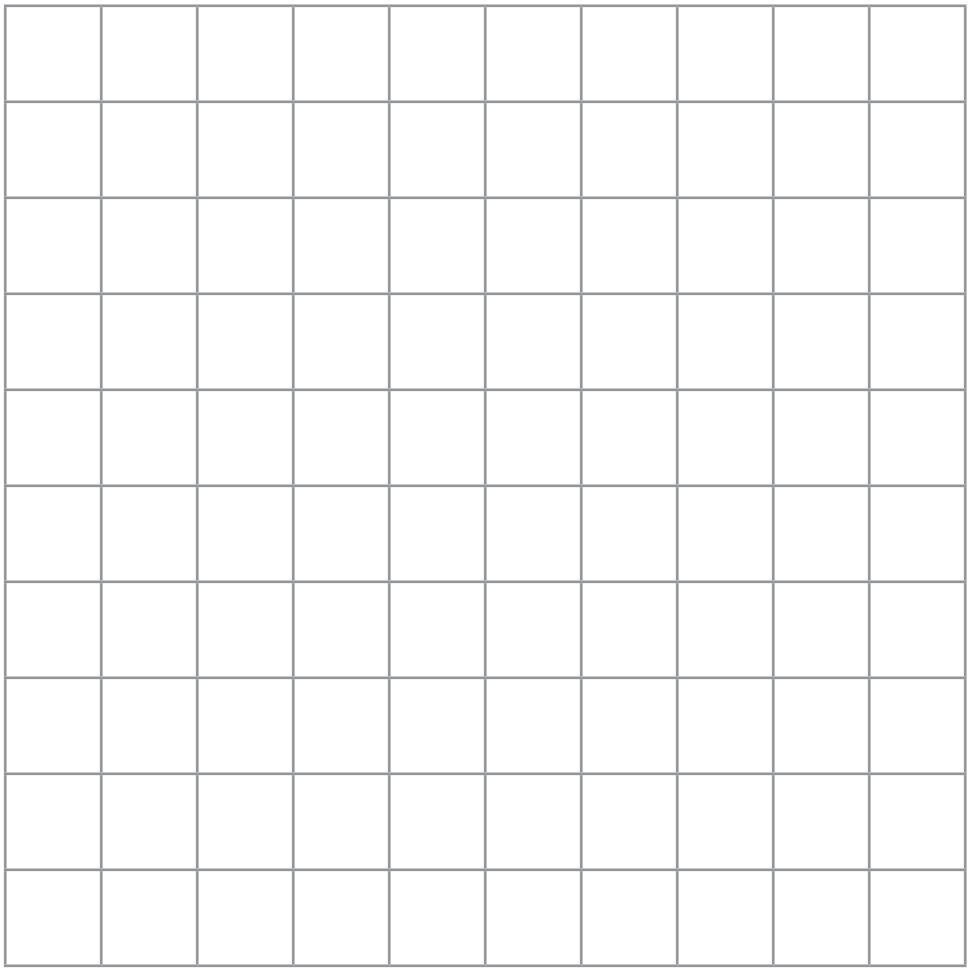
Date: _____

## 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

Name: _____

Date: _____

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