GROWING GREEN

STUDENT GUIDE

Name

School

Grade

GG_S063017
JV InvenTeams™ - Growing Green

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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 INVENTEAM 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

Each meeting within the unit includes the following:

- “Toolkit” of hands-on and minds-on skills to be learned
- List of tools and materials
- Procedure
- 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/Invention Spotlights, related patents, Extend the Learning, High School Connections, and College Connections
- Indicators of a successful meeting
- Student Self-Assessments as exit slips

**KEY TERMS**

**Cold (n):** The absence of heat energy; “coldness” is a subjective term that refers to people’s perception of low temperature, or low heat energy.

**Conduction (n):** The transfer of heat within an object or between objects in contact with each other.

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

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**INVENTOR’S TOOLKIT**

**HANDS-ON**
- General shop safety
- Recording temperature changes

**MINDS-ON**
- Evaporation
- Thermal conductors and insulators

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**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.

**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.
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 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 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 students need to think about and understand problems affecting real people and their specific needs. Researching the unique characteristics and needs of the user is essential to coming up with an effective design – as is working directly with them! Students will develop empathy for the beneficiary during the process.

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

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

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

After learning from the user, the student can further investigate.

Questions he or she might ask include the following:

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

These questions will inform research and allow the student to develop meaningful solutions.
Deciding on a Good Problem to Solve

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

SCAMPER

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

- **S** = Substitute *(playing basketball with a softball)*
- **C** = Combine *(toothbrush combined with a pencil to create a new product)*
- **A** = Adapt *(how would you eat your spaghetti without a utensil?)*
- **M** = Magnify *(how would your chair function if its legs were wider and longer?)*
- **P** = Put to Other Uses *(could your fork be used as a comb?)*
- **E** = Eliminate *(could you play tennis without a racket?)*
- **R** = Rearrange *(what if the laces of a shoe were placed on the bottom and not the top?)*

The SCAMPER technique involves the students first stating the problem they would like to solve, which defines the challenge. Then it’s a matter of asking questions, using SCAMPER to guide the students. No idea is a “good” or “bad” idea at this point.

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.
This unit will guide you to create a hydroponic gardening system for your classroom.

Your JV InvenTeam will participate in a series of activities to prepare you to build a hydroponic gardening system. The hands-on areas of focus will be learning to work with PVC (polyvinyl chloride) pipes, vinyl gutter downspouts, and the accompanying tools. The minds-on areas of focus will be water management, hydraulics, sustainable solutions relating to agriculture, and the advantages and disadvantages of growing crops hydroponically.

You will make a simple siphon to better understand how liquids can move from one container to another with the force of air pressure. You will then build a one-way valve in preparation for the construction of a manual water pump. Next, you’ll build your hydroponic gardening system using vinyl gutter downspouts, connectors, and an electric water pump. The hydroponics unit will tie in your understanding of constructing systems and water management. You will gain an understanding of the environmental, social, and economic impact of hydroponic gardening throughout the unit.

**LEARNING PRINCIPLES**

- Hydroponic gardening
- Cutting PVC pipe
- Water pressure
- Water management
- Hydraulic force
- Sustainable solutions
- Environmental impact of solutions
- Growing local food movement
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 Cut PVC Pipe and Build a Siphon
Introduction to hydroponic gardening and its advantages and disadvantages. Learn how to cut PVC pipe with a saw.

3 One-Way Valve
Learn about water and atmospheric pressure, and build a siphon. Then, build a one-way valve to be incorporated into a water pump in the next meeting. Also, gain a basic understanding of hydraulics.

4 Water Pump
Build a manual water pump and learn about major inventions in agriculture.

5 Hydroponic System, Part 1
Construct a hydroponic gardening system for the classroom using vinyl gutter downspout as the channels. Learn hydroponic gardening tips and think about the environmental impact of solutions like hydroponic gardening.

6 Hydroponic System, Part 2
Continue constructing a hydroponic gardening system for the classroom using vinyl gutter downspout as the channels.

7 Invention Extension
Conceptualize an invention project idea that incorporates one or more new skill(s) from the hydroponics unit.
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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.

**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.

**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.
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.

**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 is a PhD candidate in Mechanical Engineering from MIT.

4. If you are having difficulty coming up with your own design, check out Josh Ramos’ Cardboard Phone Stand.

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. ____________________
   ______________________
   ______________________

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 your and their comments in your next design? Describe this next design iteration in words or pictures.

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 your design 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 Competition.

SAFETY

Watch Josh Ramos’ Cardboard Videos to learn how to safely bend and cut cardboard before doing the activity.
Check out some cool videos from previous winners and finalists:

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

2. 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.

**INVENTION RESEARCH**

1. Identify an object in the room.

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 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.

4. Research the object you chose using **Google Patent Search**.

   - 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?

**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**.

**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?
Growing Green
Meeting 1: Invention Introduction (cont.)

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?

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 smart phone.

• **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.

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?

_______________________
_______________________
_______________________
_______________________
_______________________
_______________________
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.

| ![Visual Model](image) |

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.

DESIGN PROCESS NOTES
Steps of the design process are:
- identifying needs,
- brainstorming ideas,
- sketching,
- building a prototype,
- testing,
- modifying, and
- re-testing.
FOUR CORNERS GAME

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.

Alison Wong, Illustrator
DRAW IT!

Student Name

Date
Growing Green
Meeting 2: Cut PVC Pipe and Build a Siphon

Procedure

[Introduction to Hydroponic Gardening
Introduction to PVC Pipe
Review Shop Safety
Cut PVC Pipe
Brainstorm Uses for PVC Pipe
Introduction to Water Pressure
Build a Siphon
Self-Assessment]

Introduction to Hydroponic Gardening

1. Today you will learn about hydroponic gardening, or gardening without using soil.

2. Traditional gardening involves planting seeds in soil. The nutrients from the soil, combined with water and sunlight, permit growth.

3. Consider the following questions:
   • Why do you think someone might want to garden without soil?
   • What are some challenges a hydroponic gardener might face?

4. Hydroponic gardening, a trend in agricultural practice around the world, eliminates the need for soil. The term hydroponic originates from the ancient Greek “hydros,” meaning water, and “ponos,” meaning work. Nutrients are dissolved in water. U.S. Department
of Agriculture (USDA) and university developments in soilless gardening and farming will be covered throughout this unit.

5. Discuss the following advantages and disadvantages of hydroponic gardening with your class:

**Some of the advantages of soilless gardening:**

- **Environmental:** Water can be managed through reusing and recycling in a continuous, closed system. Hydroponic systems require only about 10% of the water that a soil-based system requires.

- **Location:** Hydroponic systems do not require traditional agricultural methods and settings. Crops can grow in arid, low-light, and/or low-space locations where conditions can be controlled.

- **Use in urban settings and developing countries:** Hydroponic gardens can be small, portable, low-cost, and easy to manage, allowing urban dwellers and people in developing countries to produce their own food crops.

**Siphon (n):** A tube used to bring liquid upwards from a reservoir and then down to a lower level. Once the liquid has been forced into the tube, typically by suction or immersion, flow continues without help.

**Synthetic (adj):** A substance made by chemical processes to imitate something found in nature.

**Topography (n):** Physical surface features of a geographic place indicating shape, height, and depth.

Jennifer Broutin Farah was a 2013 Lemelson-MIT Student Prize applicant. She invented SeedPod, a food growing system that allows everyday people to produce healthy food in urban settings. Her system uses aeroponic technology – think mist instead of water – and integrates sensors and mobile connectivity for ease of use. Check-out Jennifer’s two minute SeedPod Video and learn more about her many inventions on College Connection: Jennifer’s Website.

Credit: Wikimedia Commons
Growing Green
Meeting 2: Cut PVC Pipe and Build a Siphon (cont.)

Some of the disadvantages of soilless gardening:

- high start-up costs to purchase equipment and create growing spaces
- high energy costs
- intensive management of pests in the humid environment
- reliance on uncontaminated water

6. Visit How Hydroponics Works to learn more about hydroponics.

Introduction to PVC Pipe

1. You will build a hydroponic garden towards the end of this unit. To prepare for this project, you will need to get comfortable working with materials made out of vinyl like PVC pipe and gutter downspouts. You will also need to understand how water pumps work.

2. You will first work with PVC pipe. PVC is a rigid white plastic used to make the pipe used in household plumbing. It is durable and lower cost compared to copper pipe. Have you come across PVC pipes under bathroom and kitchen sinks? Have you ever seen outdoor furniture made of PVC pipe?

In the 1920s, scientist Waldo Semon experimented with synthetic rubbers to replace the more expensive natural rubber. His experiments eventually produced polyvinyl chloride (PVC). It began to be used in a number of ways such as in the production of golf balls and water-resistant coatings. Production of PVC increased during World War II, when it was used to insulate wiring on military ships. Learn more here:

History: PVC.

Source: en.wikipedia.org
Review Shop Safety

1. You will be cutting PVC pipe in this unit using saws. It is important that you use all tools safely.

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

Cut PVC Pipe

1. PVC pipe can be cut with a wide variety of tools such as a hacksaw, plastic pipe cutter, or miter saw. You will practice cutting PVC pipe by hand with a saw and miter box. Your goal is to learn to cut PVC pipe safely and to a specific length.

2. Gather with your team and get a 24” length of PVC pipe, a miter box, a saw, and a permanent marker.

3. Use the instructions below to safely cut an 18” piece of PVC pipe.

HIGH SCHOOL CONNECTION

The Landmark School from Prides Crossing, Massachusetts, a 2012 InvenTeam, invented a low-cost solar water desalination and purification system along with a seedling nursery drip irrigation unit. The units can be used for everyday life and disaster relief in coastal developing countries with arid conditions. The units can be shipped and assembled as a kit or simply as directions for local assembly using readily available materials such as bottles, PVC piping and wood.
Meeting 2: Cut PVC Pipe and Build a Siphon (cont.)

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- **Prepare the workspace.** Find a flat workspace like a tabletop or a desk. Check to make sure it doesn’t move when you apply pressure. Lay down a piece of newspaper and place the miter box on top of it.

- **Carefully measure.** Measure 18” on the PVC pipe. Use a permanent marker to draw a line where you will cut.

- **Set up the miter box.** Clamp the miter box firmly to your flat work surface. Place your PVC pipe lengthwise into the miter box so that it rests against one edge.

- **Position the saw and PVC pipe.** Fit the saw into the grooves so that you achieve a 90° angle against the PVC pipe. Make sure the saw is lined up with the line you drew on your PVC pipe.

- **Cut the PVC pipe.** Move the saw back and forth, firmly and quickly. Always keep fingers several inches away from the saw blade.

- **Check your work.** Measure the length of pipe you cut. Does it measure 18”? Is the cut straight and smooth? Talk with your partner about how you can improve your work.

4. Work in pairs to cut a 12” piece of pipe from your 18” piece, using the same instructions. You should switch roles so that everyone has the opportunity to participate in all steps of the cutting process.

SAFETY

Always wear a pair of safety glasses and a dust mask when cutting PVC pipe because cutting the pipe produces a lot of dust.

Make sure you have an arms-length in space between you and other students while you are cutting.
Brainstorm Uses for PVC Pipe

1. You have now gained hands-on skills: measuring and cutting PVC pipe.

2. Brainstorm other uses for PVC pipe using the prompts below.
   - Think of something you could build with PVC pipe. Sketch and describe your design.
   - Why would PVC pipe be a good choice in building material for this object?
   - You will learn about water pressure and flow through pipes in the next meeting. How do you think this information will help you build a hydroponics gardening system?

EXTEND THE LEARNING

Learn to cut PVC pipe with just a string for an additional challenge! Check out these images and visit Cutting PVC in a Tight Spot to see how it’s done.
Growing Green
Meeting 2: Cut PVC Pipe and Build a Siphon (cont.)

Introduction to Water Pressure

1. Think about the landscapes that surround you. It is clear that land takes various formations and shapes. While some areas of the country are flat, many more contain hills, valleys, and mountains.

2. Think about how water flow. For instance, how do you think the topography of the land impacts how water flows through it?

3. Sometimes a water source is located at a higher elevation and needs to provide water to a lower elevation. Water always “seeks its level,” meaning it flows from an area of higher pressure to lower pressure. Water pressure is directly dependent on the weight of water. Since water pressure is dependent on weight, it is also directly proportional to elevation.

4. A siphon is a tube used to move liquid over an obstruction to a lower level without the need for pumping. Read How Does a Siphon Work? to find out more.

5. Siphons work because of atmospheric pressure. The container from which the liquid is drawn from must, therefore, be open to the air. When the tube is filled, the liquid will run out of the lower end. The greater weight of the liquid in the arm outside the container determines the direction of flow of the liquid.

6. Watch The Siphon to see how a siphon works.
Build a Siphon

You are now going to build your own siphon. Follow the instructions below to build a siphon.

1. Assemble the following materials:
   - 2 clear cups
   - ¼” clear plastic tubing (1 1/2 feet)
   - food dye
   - books, erasers, or blocks to elevate one cup
   - scissors
   - plastic pipette

2. Pour 4 oz. of water into one cup. Pour 6 oz. of water into the second cup.

3. Place the second cup 6” above the first cup using a stack of books, erasers, or blocks.

4. Put 3 drops of food dye into each cup (use different colors if you want to make a new color when the water combines!)

5. Cut 1 1/2’ of plastic tubing with the scissors.

6. Place one end of the tube in one cup, and the other end in the other cup.

7. Insert the pipette into the end of the lower tube. Press on the bulb until water begins to fill the tube from the upper cup.
8. Gently pinch and remove the pipette as the water approaches the lower cup. Watch as the water travels upward in the tube from the upper cup, and then downward into the lower cup. The water will stop flowing when equilibrium is reached.

Review

1. The pipette worked as a siphon. A siphon is beneficial for the one-way transfer of water without the need of a pump. Siphons are often used in irrigation to lift water from a canal, over a dike, and into a field.

2. Irrigation systems can use pumps, too. Pumps can be manual or require energy source.

Follow-up Questions:

1. Use the information in your guide and what you saw in the video to answer the questions below.
   • Summarize how a siphon works using the following key words: potential energy, high pressure, low pressure, and gravity.
   • What allows water in a siphon to move upward as part of its level-seeking process?
     ____________________________________________________________
     ____________________________________________________________
     ____________________________________________________________
   • Can you think of some practical uses for a siphon?
     ____________________________________________________________
     ____________________________________________________________
     ____________________________________________________________
Researchers at the New Hampshire Agricultural Experiment Station (NHAES) are investigating solutions for farmers who need to meet demand for produce in the winter (off-season). These farmers want to start hydroponic gardens in greenhouses.

This controlled environment allows for greater quantities of produce, more money for farmers, and creates a supply of local food in winter months, which means they don’t have to transport their produce across long distances. Visit Sustainable Solutions: Hydroponics to learn more.

Source: commons.wikimedia.org
MY THOUGHTS

Student Name

Date
KEY TERMS

Check valve (n): A device for controlling the passage of fluid through a pipe. Allows movement in one direction only.

Gravity (n): The force that attracts a body toward the center of the earth, or toward any other physical body having mass.

Incompressible (adj): Not able to be flattened by pressure.

Procedure

- Make a One-Way Valve
- Self-Assessment

Make a One-Way Valve

1. You will need to make a one-way valve, also called a check valve, so that your manual pump will circulate water properly. Water needs to come in one way and go out the other. A check valve allows water (or air; think bike pump) to go in one direction but blocks it from going the other way.

2. If you have two check valves, then all you have to do is devise a way to pull and push water through them to make a pump. Watch Intro to Check Valves (13:57) to see how they work.

3. You will use PVC pipe and a rubber ball to make your check valve. One end of the PVC pipe is slightly bigger in diameter than the ball so water flowing toward the end of the pipe can pass easily around the ball. The tube narrows in the middle so that the ball can’t go through it. If water is flowing toward the middle of the tube, the ball will get pressed against the narrow section of PVC pipe and block the path of the water.

4. Your instructor will pair you with another student. The two of
will join forces with another pair in the next meeting to construct a manual water pump using both valves.

Follow the instructions below to make your check valve.

**Gather tools and materials.** You will need the PVC pipe components, a rubber ball, PVC cement, a permanent marker, pliers and a saw.

**Cut the rubber ball.** Cut the rubber ball according to the following diagram. Use the pliers to hold the ball securely in place. Be very careful to keep your fingers away from the saw.
Test the valve. Place the ball in the male slip adaptor. Test by blowing air in both directions to see if the ball stays in place and allows air to pass through from one end, while blocking it from the other.

Prepare the PVC pipe. Attach the male slip adaptors to the PVC pipe using a thin layer of PVC cement once the valve is functioning. PVC cement has a strong odor. Use it only in a well-ventilated area. Wear gloves to keep the adhesive from touching your skin.

Let dry. Let the attached pieces dry for 5 minutes.
Test the valve. Try testing the direction of water through the one-way valve by running water from the sink into either end. In what direction does the water flow? Use a permanent marker to indicate the direction of flow.

Clean up. Put away your tools and materials. Clean up your workspace.

One-way valves with the direction of flow marked on the PVC pipe.

Hydroponic farms can replace old structures and reduce the need for new space to grow. This is the case with a 15,000 square foot hydroponic greenhouse facility called Gotham Greens in Brooklyn, New York. The garden sits on top of an old bowling alley. Are there any abandoned lots or buildings in your community where a garden could thrive? Visit Sustainable Solutions: High-Tech Hydroponic Farm to learn more about Gotham Greens.
MY THOUGHTS

Student Name

Date
Growing Green
Meeting 4: Water Pump

Procedure

▶ Build a Water Pump
▶ Attach Pump to One-Way Valves
▶ Meet Eduardo Torrealba
▶ Research Major Inventions in Agriculture
▶ Self-Assessment

Build a Water Pump

1. You are going to work with your partner and join forces with another pair of students to build a manual water pump. Diverse groups – those that represent an array of skill sets – are typically successful groups.

2. Your team needs a miter box and a saw at your workstation. You will also need safety glasses, dust masks, disposable gloves, a measuring device, and a permanent marker.

3. Review safety procedures as a class. You should wear safety glasses at all times. You should wear dust masks when sawing or drilling. You also should wear gloves when applying PVC cement.
4. Follow the instructions to prepare your PVC pipe.
   • Cut the ¾” PVC pipe into one 2” section and label it “A”
   • Cut the 1 ¼” PVC pipe into one 12” section and label it “B”
   • Cut the ¾” PVC pipe into one 14” section and label it “C”

5. Follow the instructions on the next pages to build your manual water pump.

HISTORY

Water pumps have existed since 3000 B.C. Early pumps were made with water wheels and chutes, and used animals to provide the energy to move the wheels. Visit History: Pumps to explore the fascinating and long history of pumps.
Identifying PVC Parts

Female PVC slip adaptor

PVC pipe slip coupling

PVC pipe T-connector

PVC pipe slip bushing

Instructions: How to Build a Manual Water Pump

1. Place one of your PVC pipes labeled “A” into the top port of the PVC pipe T-connector.
2. Connect both female PVC pipe slip adaptors to the side ports of the PVC pipe T-connector.

3. Place a PVC pipe slip bushing onto the PVC pipe labeled “A” that is sticking out of the T-connector.

4. Insert the PVC slip coupling into the pipe slip bushing. Then connect your PVC pipe labeled “B” to the PVC slip coupling.
5. Place the PVC cap on one end of the pipe labeled “C.” Attach the cap with PVC cement.

6. Smooth out the inside of the other PVC slip bushing so that pipe “C” fits easily through it.

7. Slide the PVC pipe slip bushing onto pipe “C.” Attach the other PVC T-connector to the capless end of pipe “C.”

8. Now slide pipe “C” cap-first into pipe “B” while fitting the bushing to the end of pipe “B.”

9. Cement the edges with PVC cement and let it dry before using.
Attach Pump to One-Way Valves

1. Both pairs of students on your team made a check valve in the previous meeting.

2. You will attach those two check valves to the pump on either end. Follow the arrows labeled on the one-way-valves to make sure the water will only go in one end and out the other. You can test the pump with a cup of water once the PVC cement has dried.

3. Begin reading about Eduardo Torrealba on the next page after your team finishes.
Meet Eduardo Torrealba

Eduardo Torrealba is the 2013 $30,000 Lemelson-Illinois Student Prize Winner. He won for his invention called PlantLink, a soil moisture monitoring program.

Check out Eduardo’s Presentation to high school students from EurekaFest 2013 at MIT.

Eduardo Torrealba is the co-founder and CEO of Oso Technologies. He worked with four friends to develop the soil moisture monitoring invention for gardeners when he was a graduate student at the University of Illinois at Urbana-Champaign (UIUC). Eduardo received his Bachelor of Science in Mechanical Engineering from Baylor University (Texas) and his Masters of Science in Mechanical Engineering from the UIUC through a National Science Foundation Graduate Research Fellowship. He is currently on a leave of absence from the PhD program at UIUC to focus on building his company, Oso Technologies.

Who were your role models as a kid?
I was always a little different growing up. While my friends looked up to sports and movie stars, I wanted to be like Bill Gates, Jeff Hawkins, and other people who were making it possible for the world to improve on a massive scale through technology. However, I often felt discouraged because I was far from a star student. I knew that I needed to do well in school if I was going to emulate these people. The people who ended up being my ultimate role models were my parents and my science teachers. They believed in me and told me that I could accomplish great things if I worked hard and put aside any excuses.
Did you do any tinkering or inventing at a young age?
I wasn’t much of an inventor when I was younger. I was more interested in playing video games than in programming computers. This changed near the end of high school. I discovered a love for physics and engineering after reading a book on quantum physics as part of a chemistry class. That eventually led to an enjoyment of tinkering, building, and inventing that defines a huge part of who I am today. It’s never too late to become an inventor!

How did you get interested in plant-related technologies?
Describe your journey.
I became interested in plant-related technology after killing a basil plant at the start of graduate school. I wanted to find a way to become a better gardener using some of the technology I was using in my engineering research. So, I built an Internet connected sensor out of some simple electronics. From there I worked with friends of mine to improve the product until it was good enough to sell to other people.

What advice can you give kids who want to become inventors?
You have to be bad at something before you can be good at it! It is so easy to come up with an idea and then become discouraged because you don’t think you can build the product. Instead of giving up, just try to build a bad version of your idea as a starting point. You will learn so much about how to improve it on the second try just by building a bad version the first time. The best inventors I know are able to teach themselves new skills quickly and are not intimidated by their lack of knowledge in a particular area.

What do you do for fun outside of work?
When I’m not busy working on my company, I enjoy running, biking, reading science fiction novels, traveling with my wife, and building new things.
Growing Green
Meeting 4: Water Pump (cont.)

Research Major Inventions in Agriculture

1. **Agriculture** has evolved in the United States over time through a series of breakthrough inventions in the 19th and 20th centuries. What were these inventions? Who were the inventors? What problems did their inventions solve?

2. Your class will be divided into research teams. Your instructor will assign your team to research one of the following inventions:
   - Reaper/binder
   - Thresher
   - Steam engine
   - Tractor
   - Rubber tires
   - Hydraulic implement lift

3. Answer the questions below by researching your assigned invention using a patent search. You can visit [Google Patents](https://patents.google.com) or [Free Patents Online](https://www.freepatentsonline.com) to read the patent for your invention online.

   - Who was the inventor? Or inventors?
   - When was the patent granted?
   - Why was it useful?
   - What made it unique?
• Do you think this invention is still in use? If not, did it inspire subsequent inventions?

• What farming, gardening, and/or hydroponic-related inventions come from your community or state? Conduct research, including a patent search, to find out.

4. Check out the following links to learn more about inventions in agriculture:

   • Scientific Breakthroughs from USDA in 2013
   • Growing a Nation: The Story of American Agriculture

Growing plants is not just limited to Earth! Heather Hava is a PhD student in the Aerospace Engineering Sciences program at the University of Colorado Boulder with an emphasis in Bioastronautics. She is also the 2012 recipient of the NASA Space Technology Research Fellowship. Heather is a self-proclaimed space gardener and her work focuses on developing plant growth automation technologies to optimize astronaut health through human-plant interaction. She received the 2016 Lemelson-MIT Graduate Student Prize for her inventive work.

Credit: Alex Pilnick
Growing Green
Meeting 5: Hydroponic System, Part 1

INVENTOR’S TOOLKIT

Hands-on
• Assemble hydroponic system
• Grow seedlings

Minds-on
• Water management
• Hydroponic growing methods

Procedure

▶ Types of Hydroponic Systems
▶ Building the NFT System
▶ Assembling the Hydroponic System
▶ Growing and Research
▶ Wrap-up
▶ Self-Assessment

Types of Hydroponics Systems

Hydroponic gardening is an agricultural practice where plants are grown in water with soluble mineral nutrients (fertilizer), not in soil. The gardening is considered “inorganic” when soluble mineral nutrients are used. This type of growing plants was developed due to challenges in farming, such as drought, limited land to grow plants, and population growth. Advances in technology and research in the last 10 years have introduced organic hydroponic gardening, where plants are still grown in water but the nutrients require a biological ecosystem in order to be available to the plants.

You will build an inorganic hydroponic garden in a box in Meetings 5 and 6. You’ll build the system using a modified method of hydroponic gardening called “nutrient film technique,” or NFT—one of six types of hydroponic gardening. The NFT system has plants, in pots of rockwool to support roots, suspended through a slanted channel while...
the nutrient solution is pumped to the higher end. A thin film of water trickles across the plant roots to the lower end, where the solution is collected in the box and recirculated.

Discuss with your class the trend in buying “organic” vegetables.

What does this mean? How do you know that a vegetable was grown “organically”? Why is interest in organic hydroponic gardening—bioponics—well, growing?

You will work with teams to build parts of a hydroponic garden in a box for the classroom. Teams will be needed for: 1) assembling the NFT system out of vinyl gutter downspouts, 2) preparing the container for the NFT system, 3) growing the seedlings, and 4) researching other types of hydroponics and bioponics for future inventions. Read through the next two meetings and decide where you want to focus your work.

pH (n): a figure represented on a logarithmic scale from 0 to 14 that indicates how alkaline or acidic a solution is; a pH of 7 is neutral with higher values indicating more alkaline and lower values indicating more acidic; the pH of water in hydroponic gardening should be in the 5.5-6.5 range for nutrients in the water to be available to the plant roots.

Rockwool (n): A medium made from basalt rock and chalk. Seeds are placed in these fibrous germination cubes.

Soluble (adj): able to be dissolved in a specific liquid.

Sustainability (n): The quality of not being harmful to the environment or depleting natural resources, and thereby supporting longterm ecological balance.
Growing Green
Meeting 5: Hydroponic System, Part 1

Building the NFT System

The NFT System will look similar to this system that is in an office at MIT, growing arugula and cilantro.

IMPORTANT BUILDING NOTE:

JV InvenTeam grantees and anyone who orders kits via AquaPhoneix (online ordering system) will receive pre-cut/drilled pieces of vinyl downspout for their class hydroponic system. Those who will be ordering their own vinyl downspout should follow the cutting and drilling instructions in the Appendix (see page 79).

Only educators with shop experience should lead the drilling process due to safety concerns.

NFT hydroponic garden system growing arugula and cilantro.
Credit: Leigh Estabrooks
Amy Hicks and her husband, George Ferguson, grow and sell organic vegetables, plants, and cut flowers from their farm—Amy’s Garden—in Charles City, Virginia. They started gardening in their back yard in 1995, but became full-time farmers of United States Department of Agriculture (USDA) Certified Organic vegetables and flowers on 10 acres of land. Amy and George do not use pesticides or synthetic fertilizers since they are organic farmers. Instead, they manage their soil with compost and organic mulches, and practice what is called crop rotation to keep the soil productive. Their growing strategies integrate their farm production with longer-term environmental goals to support a healthy ecosystem.

Several steps are necessary to build this system, so the steps are divided between two meetings. The steps in Meeting 5 are:

- Cutting vinyl downspout in a miter box (only for those who do not receive or order kits. See note on page 41),
- Drilling holes into the downspout with a hole saw, and (only for those who do not receive or order kits. See note on page 41)
- Assembling the system.

Credit: U.S. Department of Agriculture (Fall Line Farms; cooperative, co-op; Richmond, VA.) [CC BY 2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons
Assembling the Hydroponic System

Use the two 22” pieces of vinyl downspout to fit into the bin as shown in the photo below.

- Place one piece of downspout into the container in the “portrait” orientation and make sure it fits snugly.
- Place the other piece of vinyl downspout in “landscape” orientation and put it on the other long side of the container.
- These two lengths of downspout will be the angled shelf that the downspout channels will sit on to create the trickle-down flow of nutrient-rich water.

- You received five 15” pieces of downspout with three 3” diameter holes as shown below.
• Place the five 15” pieces of downspout into the container on top of the other downspouts that form the angled shelf.

Credit: Eurah Ko
Growing Green
Meeting 5: Hydroponic System, Part 1

There is a lot to be learned about growing green—especially growing hydroponically, which is very different from growing plants outdoors in soil! Plants need the right amount of sunlight, nutrients, and a structure to support plant growth. You can find a lot of information online about hydroponic gardening. Research the topic and report to your JV InvenTeam what you learn.

While one group of students is building the hydroponic system, another group can be researching and germinating seeds that will be placed into the system once it’s built. Planting the seeds will not take very long.

• Follow the label’s instructions for planting seeds directly into the starter plugs. These are also called rockwool—an inert material for hydroponic gardening. Always wear gloves when handling rockwool.

• Dip the rockwool cubes in water with a pH of 5.5 for several minutes to an hour. You can use a pH kit to determine the pH. Add fresh lemon juice in small mounts to the water and adjust the pH to around 6.0. Rockwool is alkaline with a pH of almost 8 and plants need to grow in a system where the nutrients are most available. Nutrients are most available in a pH between 5.5-6.5. Don’t adjust the pH below 5.0, however, as this damages the rockwool fibers.

HIGH SCHOOL CONNECTION

Dr. Philson Warner founded Cornell Hydroponics, Aquaculture and Aquaponics Learning Labs in New York City. Food and Finance High School, also in New York City, is a public culinary high school. This high school is a partner with the Cornell Labs, and runs hydroponic gardens and a rooftop greenhouse at the school. The food harvested at the school is a model for sustainable food production and the students are prepared for culinary schools when they graduate.

Cornell Cooperative Extension-New York City associate Philson Warner and Food and Finance High School junior Christa Torres demonstrate Cornell’s mobile hydroponics unit.

Credit: Jennifer Tiffany/Cornell University Cooperative Extension-NYC
• Place the saturated rockwool in a pan. Put one or two seeds in each center hole of the rockwool. Gently push the seed down with a pointed object like a pencil until they are almost at the bottom of the cube. Arugula seeds will take about a week to germinate (sprout) in a warm location between 68-72 degrees.

• Don’t let the rockwool dry out: the seeds should be moist all the time.

• Once the seeds have germinated and roots begin to grow, add hydroponics fertilizer to the water that you add to the pan. Make a 1-gallon solution to have on hand according to the label. Be sure to write on the 1-gallon solution that it’s to be used for germination. A higher concentration of nutrient solution will be used for aggressive growth after the seedlings are transplanted into slotted mesh net pots.

WRAP-UP

Reconvene with your small group to discuss what you did to build and plant the classroom hydroponic garden. Talk about how you could modify the classroom garden into one of the other types of hydroponic gardens. Could the garden be modified to organically grow plants? What other types of plants would you like to grow hydroponically?
KEY TERMS

Flow rate (n): the volume of liquid that passes through a system over a specific period of time; the flow rates of the pumps used in hydroponic gardening are available in different GPH or gallons per hour

GFCI (n): a ground-fault circuit interrupter that automatically shuts off power to protect people against electric shock

ID (n): the inside measurement of the diameter a tube or pipe as opposed to the OD or the outside diameter of a tube of a tube or pipe

Intake (n): where something is taken in or enters, like water entering into a pump or air into an engine

Procedure

- Finish Building a Hydroponic System in a Box
- Meet Brian Krug
- Wrap-Up
- Self-Assessment

Finish Building a Hydroponic System in a Box

- Cut the following lengths of clear tubing with scissors:
  - Four 5" long pieces of 1/4" inner diameter (ID)
  - One 6" long piece of 1/4" ID
  - Four 3" long pieces of 3/8" ID
  - One 7" long piece of 3/8" ID
  - One 7" long piece of 1/2" ID
• Assemble the tubing using the tee fittings and hose clamps so that it looks like the configuration shown in the picture below. Make the overlap as long as possible when fitting the tubing onto the barbed ends of the black tee fittings. Use a flathead screwdriver to tighten the hose clamps on the 1/2” ID tube coming from the pump, and again where larger tubing joins smaller tubing.

• Attach the pump onto the free end of the 1/2” piece of tubing. First fit the hose clamp onto the tubing, as close to the edge as possible, and push in the pump. Then tighten the hose clamp.

• Test the tubing-pump assembly in a sink. Make sure that all of the 1/4” tubing pieces have equal flow rates. Also, look for any leaks.
which can usually be fixed by tightening or adding a hose clamp.

• Use the suction feet to attach the pump to the side of the container. The **intake** opening of the pump should be facing down. Stick the 1/4" tubing ends into each small hole in the top of the downspout pieces.

• Add 3 gallons of water to the container with the appropriate amount of hydroponics fertilizer premixed in the water for either seedlings or aggressive vegetative growth. The appropriate amount is found on the back label. The water level in the container should be about 1" above the intake opening of the pump.

• Plug the electric submersible pump into a **GFCI** extension cord. Plug the extension cord into a wall socket. Turn the pump on. Make sure that the pumped water streams in each downspout piece and that water runs down the center. If not, turn the pieces of tubing until they do. Then turn off the pump for now.

• This NFT system is modified so that the pump does not need to be on continuously. However, it needs to be on in regular intervals, applying a trickle of nutrient-rich water so that the rockwool never dries out and the plants have food.
• Plant seeds. Refer back to Meeting 5 for planting seed in rockwool if this was not done in an earlier meeting. Follow the next step once the seeds have germinated and roots have begun to grow through the rockwool. Germination will take about a week.
• Transplant seedlings into larger, 3” slotted mesh net pots. Always wear gloves when handling rockwool. Gently place additional moist rockwool with an adjusted pH into a slotted mesh net pot. Do not squeeze or remove the air pockets from the rockwool. Place the rockwool cube with the seedling and layer some more moist rockwool around it. Add clay pebbles in the top 1/3 of the net pot to add support for the growing plant and conserve moisture in the rockwool.

The classroom hydroponic system is now complete! Monitor the amount of pumped water and determine how often the water needs to be pumped through the tubing to keep the rockwool moist. You may want to add a timer to the pump so that the pump comes on once or twice an hour—including weekends and overnight, when no one is around to manually turn the pump on and off.

Water will evaporate out of the container. The water level in the container should be kept at about 1” above the intake opening of the pump. Keep the hydroponics fertilizer on hand to use as needed. Seek additional information on testing the water to monitor the pH. The pH level is used as an indicator of nutrient use by the plants. Also, the water and nutrient solution should be changed about once every week. How will you change the water? What will you do to sustainably use the water and nutrient solution?

NOTE ABOUT FERTILIZERS

All fertilizers use a numbering system to identify the amount of nitrogen (N), phosphorus (P), and potassium (K) needed for plant growth. N-P-K are always listed in this order.

Plants need nitrogen for chlorophyll production and photosynthesis. Plants use phosphorus to store and transfer energy to promote growth. Plants need potassium to promote good root development and regulation of water in the plant cells.

Hydroponic fertilizers often have large amounts of potassium. This is because good root growth is necessary for successful hydroponic growing.
Growing Green
Meeting 6: Hydroponic System, Part 2

Arugula leaves for salad (3 weeks old)

Clay pebbles for plant support

Rockwool growing medium

Roots that absorbed nitrogen, phosphorous, potassium from the film of water and nutrient solution

Arugula growing green in NFT hydroponic garden system
Credit: Leigh Estabrooks

Keep a log of how your Arugula is growing, including temperature, light, and timing interval for the pumped water and nutrient solution.

_______________________________________________________
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GG_S063017
Arugula – also known as salad rocket – is used in salads and as a topping after pizzas are removed from the oven. It is a very healthy leafy green vegetable in addition to being delicious. It has a lot of nutrients including vitamins A, K, and C plus calcium, iron, and potassium. The young arugula leaves have a milder flavor than the more mature leaves which develop a peppery or spicy flavor.

Executive Chef James Reaux puts the final touch on a Crisp Hydro-Arugula salad, which is the appetizer for the Celebrity Chef Luncheon held aboard the guided missile destroyer USS Mitscher (DDG 57). The luncheon was a part of Fleet Week. The Fleet Week celebration is an annual tradition thanking our nation’s sea-going personnel for their dedicated service to our country.

Credit: By U.S. Navy photo by Journalist 2nd Class William Mosley. [Public domain], via Wikimedia Commons

Find a recipe online for Arugula that you may like to prepare and serve to your friends.
Growing Green
Meeting 6: Hydroponic System, Part 2

Meet Brian Krug

Brian grew up on a second generation family farm in northeast Iowa. He developed a passion for horticulture through his grandfather and his involvement in Future Farmers of America (FFA). Brian’s undergraduate degree was from Iowa State University. He earned his Masters and PhD from North Carolina State University.

Brian currently works for the University of New Hampshire. Brian’s responsibilities at UNH include supporting the growers of New England with sound applied science to increase their productivity and success and providing educational opportunities for the floriculture industry. His research efforts are focused on plant nutrition, plant growth regulation, and energy efficient, sustainable greenhouse production.

Who was your role model as a kid?

Did you do any tinkering or inventing at a young age?
I took apart just about everything I could get my hands on to learn about what made it work; to this day my parents joke about how many things I took apart but was unable to get back together again.

How did you get interested in agriculture and hydroponics?
I grew up on a farm in northeast Iowa. At an early age I learned how agriculture affects everyone in the world. Through the FFA (Future Farmers of America) I learned about horticulture. I majored in horticulture in college and found a passion for growing in a greenhouse. For over 15 years my focus was on growing flowers, but have recently began focusing on vegetable crops.

What advice can you give students who want to explore a future in agriculture?
Agriculture has more facets that you can imagine; growing crops, developing new crops, designing equipment and software for agriculture, etc. Use the talents you have to be creative in agriculture.

What do you do for fun outside of work?
My family gardens in our backyard. I enjoy woodworking and traveling.
Wrap-Up

Consider how many arugula plants you would need to grow for one salad. How long would it take from planting seeds to harvesting arugula leaves? How many hydroponic systems like the one you built would you need to grow enough arugula for one salad per student on your JV InvenTeam? Think about how you could “scale-up” your production to prepare salads for your entire school.

COLLEGE CONNECTION

CityFarm is part of the City Science initiative at the MIT Media Lab in Cambridge, Massachusetts. Their group of engineers, architects, urban planners, economists, and plant scientists are rethinking the phrase, “grow it THERE and eat it HERE” to “grow it HERE and eat it HERE.” Goals include reducing water consumption in agriculture by 98% and eliminating chemicals and pesticides. Visit College Connection: CityFarm to learn more.

Source: MITcityfarm.media.mit.edu
KEY TERMS

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

Subsistence farming (n): Type of farming in which farmers focus on growing enough food to feed themselves and their families.

Growing Green
Meeting 7: Invention Extension

INVENTOR’S TOOLKIT

Hands-on
• Sketch invention project plan

Minds-on
• Research ways to incorporate new skills from this unit into an invention
• Conceptualize an invention to solve a real-world problem

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.

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

3. Invention is centered on empathy and fulfilling the need of an individual or group of people with a unique solution to a real-world problem. The most important thing today is identifying a real need and conducting research before jumping into project development.
Review Real-World Examples

1. Review the following examples with your class. These projects may inspire your design thinking.

Example 1: Guerilla Gardening in Los Angeles

Ron Finley plants gardens all over South Central Los Angeles to offer healthy alternatives in a community that thrives on fast-food eating. Check out his TED talk: Guerilla Gardening (10:42).

Example 2: Omaha Benson High School Magnet InvenTeam

The Omaha Benson High School Magnet InvenTeam from Omaha, Nebraska, invented an outdoor, self-sustaining, solar powered hydroponic gardening system. The system grows tomato plants suspended from a fence or railing. The system includes a monitoring device that automatically adds the correct amount of nutrients and adjusts water flow when needed. Visit Omaha Benson HS to learn more.

HIGH SCHOOL CONNECTION

The Hillside New Tech High School InvenTeam from Durham, North Carolina, invented a residential green roofing system for sloped surfaces. The structure supports plant growth on existing sloped roofs, which allows homeowners to reduce their home’s negative environmental impact. Visit High School Connection: Green Roofs to learn more.
Growing Green
Meeting 7: Invention Extension (cont.)

Example 3: Martin Fisher

Martin Fisher was the 2008 winner of the Lemelson-MIT Award for Sustainability. Fisher has applied his passion for improving things to the challenge of eliminating poverty in rural Africa.

In collaboration with coworkers, he has invented low-cost, human-powered irrigation pumps and other simple moneymaking tools, coupled with a sustainable and replicable supply-chain model that enables **subsistence** farmers to use the equipment to become self-reliant entrepreneurs.

This process is transforming the lives of hundreds of thousands of people living in poverty in Africa by enabling them to double or triple their family incomes. Visit Martin Fisher to learn more.

Example 4: D-Lab

The D-Lab is a center at MIT that builds a global network of innovators to design and share technologies that improve the lives of people living in poverty.

In 2010, D-Lab representatives traveled to Ecuador to provide hydroponics education to local school children and adults. The goal is that people can take ownership of the gardening and continue it beyond the training. The participants used low-cost, easy-to-find materials to build their simple hydroponic gardens.

Explore the D-Lab Photo Gallery to see photos from the trip.

Earthquakes and tsunamis hit Japan in 2011, harming plant production. Plant physiologist Shigeharu Shimamura invented a solution by moving industrial level farming indoors with controlled conditions. He uses LEDs that produce light at wavelengths that green plants can use for photosynthesis. He is already producing 10,000 heads of lettuce each day, 2.5 times faster than before. His control of temperature, humidity, and irrigation also reduces water usage. Visit Sustainable Solutions: Indoor Veggie Factory to learn more.

Source: en.wikipedia.org
Example 5: InvenTeams

Flip back through this unit and check out the High School Connection pop-outs. Some are examples of former InvenTeams projects related to hydroponics, water management, and/or gardening.

These projects all demonstrate a clear beneficiary, a unique solution, and technological means for solving a real world problem. Moreover, all of these students connected with local partners and mentors to facilitate the completion of their project.

Your idea should be ambitious enough to span the course of an academic year. However, it should also be realistic and doable.

Visit the InvenTeams Website to search current and past teams to get more information about their projects.

Identify a Need

1. Reflect on the new toolkit of skills you have acquired in this unit. You have gained minds-on skills such as understanding hydroponics, water pressure, water management, hydraulics, sustainable solutions, and the grow local movement. You have practiced hands-on skills such as cutting PVC pipe and vinyl downspout, and building a siphon, check valve, manual pump, and hydroponic system. You have learned how to use new tools such as a saw and drill.

2. Invention is centered on empathy and fulfilling people’s needs.

3. 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.

4. 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 has a partnership with a “sister city” in another country.

5. For additional information on problems/needs in other countries, explore the World Bank website.
Growing Green
Meeting 7: Invention Extension (cont.)

6. Share your ideas with your team and work together to brainstorm new ones. Apply your hands-on and minds-on toolkit as you brainstorm. Examples are below:
   - Modify your hydroponic system to meet a real-world need
   - Address an agricultural need
   - Address a water management need
   - Focus on increasing the accessibility and easing the transport of fresh produce in your region
   - Incorporate hydraulics into your invention
   - Work with a saw and/or drill in the construction of your invention

7. Use the Invention Challenge Brainstorm worksheet at the end of this meeting to develop and track your team’s ideas about needs you would like to address.

Brainstorm Solutions

1. Once you decided on a need to address, 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 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. Use the SCAMPER technique, you would first state the problem you would like to solve. Then, ask questions about it using the SCAMPER checklist.
4. Do some personal brainstorming using SCAMPER on the worksheet at the back of your guide.

5. Bring teams together so that students can discuss their ideas with their team and streamline them. Have teams 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 guides.

2. Ask yourself the following questions (also listed in your guide) 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 hydroponics, water management, and/or gardening 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.

4. Share your plans with the class if time allows.

5. If you are interested in continuing your work, consider applying for an InvenTeams grant!

Conceptualize an Invention Idea

- How can Internet research provide additional information pertaining to your need and user?
- Start thinking about how you can meet this need with new skills.
- How might you incorporate your acquired skills from other JV InvenTeam units into your project idea?
- Be sure your invention doesn’t already exist. Search for related patents online. If a version already exists, what modifications can be made? Remember, inventions often build from previously existing products to improve them in some way.
- What additional skills would you need to develop to build your project? Could you realistically learn them in a short period of time?
INVENTION CHALLENGE BRAINSTORM

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

WHO will you help?

WHAT will you invent?
What problem do you want to solve?

________________________________________

S = Substitute
(Playing basketball with a softball.)

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

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

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

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

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

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

Our JV InvenTeam members are:

The product we are inventing is: ____________________________ to

(\textit{short description of what it does})

______________________________________________________________.

It is useful for ____________ because ____________________________.

(\textit{the user}) (\textit{description of the need or problem})

It is unique because ________________________________________

(\textit{description of how it’s different from other solutions})

______________________________________________________________.

It functions by _______________________________________________

(\textit{description of how it works})

______________________________________________________________.

The tools we need are:
_____________________________________________________________

_____________________________________________________________

The materials we need are: ___________ ___________ ___________ ___________

_____________________________________________________________

_____________________________________________________________

_____________________________________________________________

The estimated total cost of our invention will be: $_______________
Meeting 5: Optional Cutting and Drilling Instructions for Vinyl Downspout

Materials and Tools

**Materials and tools listed below are provided in kits:**

- Safety glasses, dust mask, and latex-free gloves
- Miter box set (should contain box, offset clamps, saw)
- Clamps

**Materials and tools listed below are NOT provided in kits:**

- Power drill (corded and battery-powered)
- 3” hole saw
- Hole saw arbor
- 7/16” drill bit
- 5/64” hex key
- Screwdriver
- Utility knife
- Vinyl downspout

Procedure:

- Cutting Vinyl Downspout
- Drilling Holes in Vinyl Downspout
- Fabricating the Hydroponic System
Cutting Vinyl Downspout

• Before you begin the activity, review the general shop safety rules:
  • Wear safety glasses, dust masks, and latex-free gloves.
  • If you are in doubt about how to use a tool, ask!
  • Have a plan for what you are going to do with the tool.
  • Be mindful of others who might enter into your workspace accidentally.
  • Have a balanced stance while using a tool.
  • Remove all jewelry, watches, and loose clothing before working with machinery.
  • Pin up long hair and wear closed-toed footwear.
  • Never work when you are tired or not focused.
  • Leave the workspace cleaner than you found it.

• Gather all tools and materials.

Credit: Eurah Ko
Meeting 5: Optional Cutting and Drilling Instructions for Vinyl Downspout

• Mount the miter box onto a flat, stable surface (e.g., a heavy desk or work bench). Clamp the box onto the surface, one clamp on each side. Ideally, the box shouldn’t shake at all when cutting material. If the box or surface wobbles, cutting the material will be significantly more difficult.

• Measure and mark with a permanent marker where you want to cut the downspout for practice.

• Place the downspout in the miter box and align the cut mark with the 90-degree slot in the box. Then place a spare piece of wood on the side of the downspout that is not in contact with the miter box. This will prevent the thin-walled downspout from deforming too much with the downward pressure of cutting.
• Place the offset clamps in the holes of the miter box, one on each side of the slot, with the thinner side facing the wood.

![Offset clamps](image1)

Credit: Eurah Ko

• Turn the clamps so that they press the wood and downspout against the miter box. The wood and downspout should be held tightly in place.

![Offset clamps](image2)

Credit: Eurah Ko

• Begin cutting with the saw by placing the blade in the slot. Cut the material by making long strokes, engaging as much of the saw blade as possible. Don’t apply a lot of downward pressure; it’s the back-and-forth motion of the saw teeth that cut material, not the downward force.
Meeting 5: Optional Cutting and Drilling Instructions for Vinyl Downspout

• Continue sawing until the ridge on the top of the saw runs against the slot. The ridge should be wider than the slot, to prevent the saw from going down any further. The material should be cut all the way through. Turn the clamps to loosen them and carefully remove the cut parts.

Drilling Holes In Vinyl Downspout

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

1. Gather all tools and materials.

2. Mount the miter box onto a flat, stable surface like you did to cut the vinyl downspout. Clamp the box onto the surface, one clamp on each side. The box shouldn’t shake at all when cutting material.

3. Mark the center of the hole that you want to drill with the hole saw. The hole should be centered within the downspout which is 1.5” away from the side.
Meeting 5: Optional Cutting and Drilling
Instructions for Vinyl Downspout

• Make sure the drill is not powered (i.e., unplugged or battery is removed). The chuck is the part of the drill that holds the bit, and should be in two parts. Loosen the chuck. Hold the part closer to the drill trigger with one hand, then turn the other part with your other hand. Insert the hole saw assembly and tighten the chuck. Tightening the chuck is almost the same as loosening it, except that now you turn in the other direction.

• Power the drill — plug it in or snap in the battery. There should be a forward/reverse button on the side of the drill, near the trigger. Press the button so that the drill runs in reverse. You want the drill to run in reverse because the teeth of the hole saw are very large compared to the thickness of the downspout walls. If the hole saw was run forward, the teeth would tear out the plastic and leave a very rough edge.
• Press the trigger. The drill should be running counter-clockwise. On the top of the drill is a switch that toggles between high speed and low speed. If there are numbers on the switch, the low speed corresponds to the lower number. Move the switch to the low speed position.

• Place the tip of the hole saw on the desired center of the hole. Keep the drill perpendicular to the downspout. You can ask other students to look at the drill from the side and make sure it isn't tilted. Run the drill slowly, applying a moderate downward pressure. Make sure that the hole saw doesn't cut into the bottom of the downspout. Use a utility knife to clean rough edges, then use a paper towel to dust off all surfaces.

Credit: Eurah Ko
Meeting 5: Optional Cutting and Drilling
Instructions for Vinyl Downspout

- A plug of vinyl will probably be stuck in the hole saw. To remove it, first unplug or remove the battery from the drill so that it isn’t accidentally turned on while handling the hole saw. Then put a screwdriver into the speed slots on the side of the hole saw, and move it around to push out the plug.

Note: The battery is removed for safety!
Fabricating the Hydroponic System

• Measure the inside distance between the two sides of the container you’re using for the hydroponic system (red arrow in picture below). Be sure to measure from the lower half of the container’s sides, since it may be narrower than the top half. Mark that length on a piece of downspout and cut it to length.

Place the downspout into the container (it should be turned in the “portrait” orientation, shown above left), and make sure it fits snugly.

• Measure and cut another length of downspout that is slightly shorter than the previous piece. Turn it in the “landscape” orientation and put it on the other long side of the container. These two lengths of downspout will be the angled shelf that the downspout channels will sit on to create the trickle-down flow of nutrient-rich water.
• Measure and cut five 15” lengths of downspout for the channels.

• On each 15” piece of downspout, drill a 7/16”-diameter hole. The hole should be 1” from the edge and roughly centered. Make sure that the drill is running forward when drilling the hole.

• On each 15” piece of downspout, drill three 3”-diameter holes. These holes should be evenly spaced. Make sure that the drill is running in reverse, like it was during practice.

• Place the five 15” pieces of downspout into the container on top of the other downspouts that form the angled shelf.
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