STUDENT GUIDE
# TABLE OF CONTENTS

**Activity Overview**
- Introduction to JV InvenTeams ................................................. P4
- Lab Safety Rules .................................................................. P15
- Bioplastic Reference Sheets .................................................. P17

**Meetings**
1. Invention Introduction ......................................................... 1
2. Inventing for a Sustainable Future ........................................... 9
3. Reuse and Explore ................................................................. 21
4. Experimenting with Bioplastics .............................................. 35
5. Optimizing Our Bioplastic Invention ..................................... 47
6. Prototype ........................................................................... 59
7. Communicating Ideas ............................................................ 71
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 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:

- “Lab coat” 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.

**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.
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/. 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.
You will develop sustainable bioplastic prototypes made from benign materials in this Green Chemistry unit. You will learn about the life cycle of conventional petroleum-based plastics and consider how each stage of the life cycle could be improved upon to make the process more sustainable. You will learn about the role that Green Chemistry plays in intentionally designing chemical products that are safer for humans and the environment. During your various trials, you will experimentally determine the role that the concentration and pH of the solution play in breaking down the starch into polymers and monomers. You will also learn how the type and size of starch granules influence the flexibility of your bioplastic. You will employ these chemistry principles to optimize your bioplastic formulation to create alternatives to plastics currently in use. Finally, you will consider improvements on the design as part of the prototyping process.

You will gain both minds-on and hands-on skills in Green Chemistry to expand your toolkit. Minds-on skills include understanding the role of inventing in Green Chemistry, describing chemical reactions, creating a product procedure, and communicating with others about your invention. Hands-on skills include measuring wet and dry materials, safely handling benign materials, and formulating and optimizing bioplastics. You will learn what it means to be an inventive thinker and will practice inventive thinking as you progress through the unit.

**LEARNING PRINCIPLES**

- Green Chemistry
- Chemical reactions
- Laboratory safety
- Prototyping
MEETING SYNOPSIS

1 Invention Introduction
Do warm-up activities and discuss invention. Play “Four Corners” to help the educator assign diverse teams.

2 Inventing for a Sustainable Future
Learn about laboratory safety, inventing, and Green Chemistry. Create benign lava lamps that use nontoxic materials that easily decompose.

3 Reuse and Explore
Demonstrate an understanding of how plastics are produced when a starch is heated in the presence of an acid. Reuse, experiment, and test the components of your benign lava lamp to examine the properties of a bioplastic in different environments.

4 Experimenting with Bioplastics
Comply with laboratory safety procedures to create bioplastics, compare your properties, and identify properties needed for your unique bioplastic prototype.

5 Optimizing Our Bioplastic Invention
Examine the role that concentration and pH of the solution play in the properties of a bioplastic. Use your knowledge of bioplastic properties to brainstorm ideas for a prototype.

6 Prototype
Optimize the bioplastic-making process to create a unique bioplastic with specific properties needed to create your prototype. Write a pitch to communicate about your invention.

7 Communicating Ideas
Communicate a purposeful invention that uses your new minds-on and hands-on skills from Green Chemistry.
JV INVENTEAMS™
GENERAL SHOP SAFETY RULES

Post these safety rules at the start of Meeting 1 and keep them posted throughout the unit.

SAFETY

1. Always get your teacher’s approval before conducting a lab. Never experiment on your own.

2. Always wear safety gloves and goggles during labs from pre-lab setup to post-lab cleanup, or when your instructor tells you to do so.

3. Read and follow all warning labels on substances being used.

4. Be sure your teacher is aware of any allergies you may have.

5. Carefully follow all instructions when conducting a science activity.

6. Keep all materials used in the science activity away from your mouth, nose, and eyes.

7. Do not place your hands on your face when conducting—or cleaning after—an activity.

8. Never taste anything during a science activity.

9. Tie back long hair, and secure loose clothing and dangling jewelry.

10. Safety equipment must remain in good working condition. Do not play with it.

11. Tell your teacher immediately if an injury, spill, or other accident occurs.

12. Clean up your work area after conducting a science activity.

13. Wash your hands with soap and water after completing a science activity.
BIOPLASTIC REFERENCE SHEET

**pH SCALE AND STRENGTH**

<table>
<thead>
<tr>
<th>pH</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strong Acid</td>
</tr>
<tr>
<td>2</td>
<td>Strong Acid</td>
</tr>
<tr>
<td>3</td>
<td>Strong Acid</td>
</tr>
<tr>
<td>4</td>
<td>Strong Acid</td>
</tr>
<tr>
<td>5</td>
<td>Strong Acid</td>
</tr>
<tr>
<td>6</td>
<td>Strong Acid</td>
</tr>
<tr>
<td>7</td>
<td>Neutral</td>
</tr>
<tr>
<td>8</td>
<td>Baking Soda</td>
</tr>
<tr>
<td>9</td>
<td>Baking Soda</td>
</tr>
<tr>
<td>10</td>
<td>Baking Soda</td>
</tr>
<tr>
<td>11</td>
<td>Baking Soda</td>
</tr>
<tr>
<td>12</td>
<td>Baking Soda</td>
</tr>
<tr>
<td>13</td>
<td>Baking Soda</td>
</tr>
<tr>
<td>14</td>
<td>Strong Base</td>
</tr>
<tr>
<td>15</td>
<td>Strong Base</td>
</tr>
<tr>
<td>16</td>
<td>Strong Base</td>
</tr>
<tr>
<td>17</td>
<td>Strong Base</td>
</tr>
<tr>
<td>18</td>
<td>Strong Base</td>
</tr>
<tr>
<td>19</td>
<td>Strong Base</td>
</tr>
</tbody>
</table>

**STARCH**
- Rice
- Corn
- Tapioca
- Potato

**GRANULE SIZE**
- 2 microns
- 3-8 microns
- 5-30 microns
- 100 microns

**BIOPLASTIC FORMULATION**

- Starch: 2 tsp + additive: 1 tsp + water: 2 tsp + plasticizer: 2 tsp = product

**STARCH** + **ADDITIVE** + **WATER** + **PLASTICIZER** = **BIOPLASTIC**

- Strong: Flexible
- Weak: Rigid
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.

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

**Materials**
- Student guides
- Tape
- Cardboard and scrap materials from the recycling bin
- Problem Strips
- Self-Assessments

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

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.

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.

1. 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.

2. 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?

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.

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**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.

**MIT MOTTO “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.

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

3. Before you start, watch Josh Ramos’ Cardboard Videos to learn some cardboard cutting tips and tricks. Josh earned his PhD in Mechanical Engineering from MIT in 2018.

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

THINK ABOUT YOUR INVENTION

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

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

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

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

5. How would you incorporate 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 Josh Ramos’ Cardboard Videos to learn how to safely bend and cut cardboard before doing the activity.
Watch Some Invention Videos

Each year, teams of undergraduate and graduate students apply for the Lemelson-MIT Student Prize Competition. Check out some cool videos from previous winners and finalists:

- **Julie Bliss Mullen’s invention brings clean water to people everywhere** (2:00)
- **Chen Wang, Chandani Doshi, Grace Li, Jessica Shi, Charlene Xia, Tania Yu’s invention makes life easier for the blind** (2:30)
- **Ramesh Raskar’s inventions improve people’s lives** (4:06)

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.

Research an Invention

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. Explain that Google Patents list U.S. patents as well as international patents. Patents are sequentially numbered; for example, search for “student desk” and look at the images for US7571959B2.


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?

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?

INVENTOR SPOTLIGHT

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.
Discuss Improvements to an Invention

Think about a timeline of your daily routine. If you could improve one product or process during your typical day, what would it be? In your group, discuss the following:

1. How might you go about making the improvement? Describe your process.

2. What might be some challenges to meeting this need?

3. Thinking further, do you notice anyone in your family or community who struggles to complete a certain task?

4. 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.

WATCH VIDEOS ABOUT THE DESIGN PROCESS

1. Watch the [MIT Design Process Videos](#).

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

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

   • Safety is the number one priority!

   • Watch tutorial videos before using new tools and materials.

   • Ask for help. Don’t guess, especially about how a tool works.

   • Consider all ideas. No idea is “dumb.” As an inventor, focus on the ideas with the most potential when developing a prototype.

   • Embrace failure. Failure is a part of the invention process!

   • Value your team. Everyone brings different skill sets and knowledge to the table.

2. Diverse teams are successful teams.

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

Self-Assessment

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

INDICATORS OF A SUCCESSFUL MEETING

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

<table>
<thead>
<tr>
<th>Types of Team Members</th>
<th>Your Interests and Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formulator</strong></td>
<td>Sounds most like me</td>
</tr>
<tr>
<td>I like to measure and mix things up.</td>
<td>Sounds almost like me</td>
</tr>
<tr>
<td><strong>Talker</strong></td>
<td>Sounds a little like me</td>
</tr>
<tr>
<td>I like to talk to people and I enjoy public speaking.</td>
<td>Sounds least like me</td>
</tr>
<tr>
<td><strong>Doodler</strong></td>
<td></td>
</tr>
<tr>
<td>I like to draw things and express my thoughts through drawing.</td>
<td></td>
</tr>
<tr>
<td><strong>Organizer</strong></td>
<td></td>
</tr>
<tr>
<td>I like to organize people and things.</td>
<td></td>
</tr>
</tbody>
</table>

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.

```
FORMULATOR

DOODLERS

CLASSROOM

ORGANIZERS

TALKERS
```
KEY TERMS

Benign (n): not harmful in effect.

Design flaw (n): a design that fails to meet requirements or to serve customer needs.

Green chemistry (n): the design of chemical products or processes that reduce and/or eliminate the use or generation of hazardous substances.

GREEN CHEMISTRY
MEETING 2: INVENTING FOR A SUSTAINABLE FUTURE

Tools
- 250-mL glass beaker, 2 per student group
- 400-mL (12 oz.) glass bottle, 1 per student group
- Aluminum tray, 1 per student group
- Stirring rod, 1 per student group
- Teaspoon (tsp.) measure, 1 per student group

Materials and Lab Supplies
- Wax pencil, 1 per student group
- Protective gloves, 1 pair per student
- Protective goggles, 1 per student
- Student Guides, 1 per student
- Lab Safety Rules
- Baking soda

Procedure
This meeting will cover laboratory safety, inventing, inventing green, and making lava lamps.

- Why Invent with Green Chemistry?
- Pre-Lab: Inventing with Intention
- Introduction to Lab Safety
- Lab Preparations
- Lab: Make a Greener Lava Lamp
- Post-Lab Cleanup
- Reflection: Green Chemistry Invention
- Journal Log
- Self-Assessments
- Indicators of a Successful Meeting
**WHY INVENT WITH GREEN CHEMISTRY?**

*Green chemistry* is the science of designing chemical products or processes to reduce and/or eliminate the use or generation of hazardous substances. Different from other sciences that study what something does, *green chemistry* focuses on the building blocks of a product to make it more environmentally friendly. John Warner, co-founder of the field of *green chemistry*, invents sustainable *solutions* to hazardous materials through chemistry. He has 187 molecular design patents and inventions to his name. He started the Warner Babcock Institute for *Green Chemistry* and leads a team of green chemists in developing green technology at the molecular level.

Listen to why John thinks inventing sustainably at the molecular level is important. [John Warner, Invention Education and Green Chemistry](#).

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Want additional information on John Warner? [Read his Inventor Profile here.](#)
QUESTIONS FOR THE VIDEO:

1. List two examples of **green chemistry** inventions:

________________________________________________________________________

________________________________________________________________________

2. Chemistry is involved in what industries?

________________________________________________________________________

________________________________________________________________________

3. What human and environmental impacts have these industries created and how?

________________________________________________________________________

________________________________________________________________________

4. Why is there a need for sustainable invention?

________________________________________________________________________

________________________________________________________________________

_I will make the green chemistry invention pledge to learn science to improve the way we make and do things for the health of both people and the environment._

X _______________________________________________________________________

PRE-LAB: INVENTING WITH INTENTION

Inventing for a sustainable future involves thinking about the environment at the earliest stage of design. The inventive mindset taps into the creativity and curiosity of inventors, artists, and scientists. Designing with the environment in mind involves thinking about the interaction of matter, also known as chemistry.

Chemistry consists of the fundamental makeup of all of the products we use and consume. However, chemistry sometimes has a negative reputation when it comes to the environment.
There are a lot of products that have been created in a way that is hazardous, wasteful, and damaging to the environment.

**Green chemistry** is an approach that puts chemists in the role of the inventor. It helps them intentionally design chemical products that are safer for humans and the environment. **Green chemistry** is often described as the science of creating solutions and sustainable products. It focuses on reducing or eliminating pollution at the earliest design stage of a material, as well as in its use.

Green chemists keep in mind their invention’s impact on both human and environmental health. They are inspired by nature since nature is able to “invent” without causing harm. The traditional lava lamp contained harmful chemicals that create toxic waste. Therefore, it needed to be re-invented to make a sustainable solution.

Behind every invention is a person or team of people who recognized a problem or an opportunity and invented a solution. The object of this experience is to apply inventing principles and infuse them with an understanding of **green chemistry**. Inventing is a balance between discovery and creativity. The intentional invention of materials that are “benign by design” is at the core of **green chemistry**.

Let’s create a non-harmful, or benign, lava lamp by using nontoxic materials that will easily decompose. Looking at our starting materials, how do we know that they are safer for both us and the environment?

---

Carbon tetrachloride, a liquid ingredient, was used in the formulation of very early lava lamps. It is a carcinogen, which is a substance capable of causing cancer in living tissue. Tetra is a prefix meaning “four” and chloride is a compound of chlorine.

The chlorine atoms in carbon tetrachloride are a different form and molecular structure, which can cause cancer in humans. Look at the image below to see its structure.

---

Learn more about how traditional Lava Lamps are made here.
INTRODUCTION TO LAB SAFETY

Discussing lab safety helps set the tone to introduce science experiments in the classroom. It introduces safe practices and helps you understand why these practices are used. Refer to the best practices recommended by the American Chemical Society:

1. Always get your teacher’s approval before conducting a lab. Never experiment on your own.

2. Always wear safety gloves and goggles during labs from pre-lab setup to post-lab cleanup, or when your instructor tells you to do so.

3. Read and follow all warning labels on substances being used.

4. Be sure your teacher is aware of any allergies you may have.

5. Carefully follow all instructions when conducting a science activity.

6. Keep all materials used in the science activity away from your mouth, nose, and eyes.

7. Do not place your hands on your face when conducting—or cleaning after—an activity.

8. Never taste anything during a science activity.

9. Tie back long hair, and secure loose clothing and dangling jewelry.

10. Safety equipment must remain in good working condition. Do not play with it.

11. Tell your teacher immediately if an injury, spill, or other accident occurs.

12. Clean up your work area after conducting a science activity.

13. Wash your hands with soap and water after completing a science activity.
LAB PREPARATIONS

Roles for today’s lab:

Formulator (Name): _____________________________________________

Talker (Name): _________________________________________________

Doodler (Name): ________________________________________________

Organizer (Name): ______________________________________________

Inventing with green chemistry is a team sport. Each person on a team has an important role with responsibilities. Suggested roles and responsibilities are:

**Formulator**—responsible for chemicals

**Talker**—responsible for reading the procedure and communicating results

**Doodler**—responsible for recording observations

**Organizer**—responsible for setting up all non-chemical materials and for cleaning up glassware

Decide who will be in each role today. Consider taking other roles in upcoming labs.

REMINDERS

- Review the safety rules.
- Read through the lab before you start.
- Organize all of the materials you are going to need at your lab bench or station.
- Put on protective gloves and goggles before starting the lab.
- Pour any liquids over the aluminum tray.

STUDENT NOTE

Wipe down the teaspoon if you are using the same teaspoon for different ingredients.

Your instructor will keep the lava lamps for the next meeting. The “lava” will separate into layers as it sits.
LAB: MAKE A GREENER LAVA LAMP

Follow Steps 1 – 12 carefully to make a greener lava lamp.

Beaker #1: 250 mL
1. Measure 100 mL of vinegar in the 250-mL beaker over the aluminum tray.
2. Add 10 drops of natural blue food coloring, then stir with the stirring rod.
3. Slowly add ½ teaspoon of guar gum and stir. Let this sit for 2–5 minutes.

Beaker #2: 250 mL
4. Measure 100 mL of lukewarm tap water in the other 250-mL beaker.
5. Add 1 teaspoon of baking soda to the water.
6. Pick another color of natural food coloring and add 5 drops to the water and baking soda, then stir.

Glass Bottle: 400 mL
7. Use the wax pencil to label the 400-mL (12 oz.) glass bottle with “Lab Only” so it is clear that the bottle is no longer to be used for drinking purposes.
8. Fill the 400-mL (12 oz.) glass bottle halfway with vegetable oil. Let it sit for 2-5 minutes.
9. Slowly pour 100 mL from Beaker #1 (blue vinegar and guar gum solution) into the bottle containing the oil.

10. While stirring the contents of Beaker #2 (baking soda and water solution), slowly pour 10 to 20 mL at a time from Beaker #2 into the bottle to keep the lava from overflowing. You will want to add a total of 75 mL from Beaker #2 into the bottle.

11. Observe!

12. Leave the bottle on the tray. Your educator will cap it and store for the next meeting.

**TIPS AND TRICKS**

Add the group’s name to the tray.

Always label beakers and bottles to identify the experiment.

Hold the dropper perpendicular to the substance you are dropping the liquid into.

Measure liquid amounts accurately by looking from the side of the beaker.

Measure dry substances by leveling across the top of the measuring spoon. Use a lab implement or the side of the baking soda box to level.
POST-LAB CLEANUP

- All materials are safe to pour down the drain.
- Wipe any oil residue with a paper towel before washing the labware.
- Clean beakers, teaspoons, and stirring rods in a warm, soapy water bath with 30 mL of vinegar added.
- Dry the tools and lab equipment, then store them properly.
- Your instructor will store the lava lamps for the next meeting.

REFLECTION: GREEN CHEMISTRY INVENTION

Congratulations! You have just created a safer, cheaper, and equally effective lava lamp! Unfortunately, traditional lava lamps aren’t the only invention with a design flaw. Many products have the design flaw of being harmful for us and the environment. That’s why we need more inventors using green chemistry to create sustainable solutions.

As you have learned, green chemistry is the field of study that specializes in making products while considering sustainability. Green chemists work with today’s technologies and scientific procedures to invent products— inventions—that are useful and unique. These are judged based on three criteria: 1) safety, 2) cost, and 3) performance. The invention must be able to be produced at a low cost to be successful in the marketplace. The invention must also be safe for the people creating it, the people using it, and the environment where it is being produced and being used. In addition, for a green chemistry invention to be viable, it must perform well.
Amazingly, chemistry is involved in pretty much everything—from eating food to the shampoo you use. How your clothes were made, the formulation of the toothpaste you used, and how you got to school today all involved chemistry. Now, wouldn’t it be great if we were able to do all of those things in a more sustainable way? That’s what we’re going to be working on in our upcoming activities: how to create more sustainable inventions using green chemistry.

**JOURNAL LOG**

Journal logs provide a space to reflect and write observations. Content, original thoughts, and creativity are valued over organization. A journal log page is provided at the end of each meeting guide.

Suggestions for general note-taking:
- Indent when introducing a new idea,
- Make use of both numbered and alphabetical lists, and
- Title the page.

Reflective note-taking is important, too. You should:
- Write notes for a set amount of time (5 minutes at the end of every meeting).
- Feel free to write your own thoughts. Your notes will not be shared with the class.
- Take notes in both words and drawings.

Technical and scientific note-taking include both general and reflective note-taking. In your Journal Log, practice what green inventors would do:
- Write summaries of your work each day,
- Sign your notebook or log at the end of each day,
- Date each entry,
- Write both quantitative and qualitative observations,
- Avoid using personal pronouns,
- Cite who you worked with, and
- Use key terms and other vocabulary introduced each day.
Please answer Extend The Learning questions in your journal logs.

1. What chemical reactions caused the lava lamp to act the way it did?

2. Did you create a homogenous or heterogenous mixture?

3. What caused the movement that took place in the lava lamps?

4. What layer is more viscous?

SELF-ASSESSMENTS

Please turn in your completed self-assessment as an exit slip when you leave.

INDICATORS OF A SUCCESSFUL MEETING

You are able to define green chemistry. You understand the importance of laboratory safety. You also consider how to make products friendlier or greener for the environment and can explain the three criteria of green chemistry. Additionally, you wrote a summary of your work in a daily log.
**KEY TERMS**

**Chemical reaction (n):**
a change in which new substances (products) form from starting materials (reactants).

**Dilute (v):** to add solvent (such as water) to a solution without the addition of more solute, thereby decreasing the solution’s concentration.

**Environment (n):** the surroundings or conditions in which a reaction takes place.

**Evaporation (n):** the action of turning a liquid into vapor.

**Extraction (n):** the action of taking something out.

**Filtration (n):** the action of filtering or removing something in a solution.

**Mold (v):** to form a shaped object out of an easily manipulated material like a plastic.

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**GREEN CHEMISTRY**
**MEETING 3: REUSE AND EXPLORE**

**Tools**
- 250-mL glass beakers, 4 per student group
- Aluminum tray, 1 per student group
- Hot plate, 1 per student group
- Heat-resistant gloves, 1 pair per student group
- Squeeze bottle, 1 per student group
- Stirring rod, 1 per student group
- Your group’s lab-made lava lamp
- 150-mL funnel

**Materials and Lab Supplies**
- Filter paper, 2 pieces per student group
- Wax pencil, 1 per student group
- Paper clips/wire hooks, 3 per student group
- Protective gloves, 1 pair per student
- Protective goggles, 1 pair per student
- Your Student Guide
- Alcohol

**HANDS-ON**
- Liquid separation techniques
- Evaporation, filtration, and extraction
- Measuring skills

**MINDS-ON**
- Reactions change in different environments
- Lifeline vs. life cycle of bioplastics
- Components of a chemical reaction
- Describe chemical reactions
**Procedure**

This meeting will cover:

- Pre-Lab: Reacting to Reactions
- Lab Preparations
- Lab A: Dissect and Identify
- Lab B: Experiment and Test with Undiluted and Diluted Solutions
- Post-Lab Cleanup
- Reflection: Who Knew?
- Journal Log
- Self-Assessments
- Indicators of a Successful Meeting

**PRE-LAB: REACTING TO REACTIONS**

Our everyday lives consist of many different reactions. We react to hearing a friend’s story or smelling freshly baked cookies. We constantly react to what is going on in our lives and our environment. We are often the reactant and we undergo a reaction based on what is added to our situation. This causes a product, or an outcome, which is what we do next. The same components (reactants and reagents) are present in chemical reactions.

![Chemical Reaction Diagram]

**Reagents** react with **reactants** to create a new product. For example, imagine you are the reactant and you smell freshly baked cookies. Your reagent is the smell of cookies. You may undergo the reaction of suddenly feeling hungry for cookies! The product is your hunger.

Write the chemical reaction of the cookie example below.

```
________ + ________    Reaction    ________
```
In the last meeting, you were able to make a more sustainable lava lamp using the principles of green chemistry. The traditional lava lamp was made with materials unsafe to dispose of in a landfill. Currently, many products have the design flaw of not being sustainable. It is critical to consider the entire life cycle when designing green chemistry inventions.

**Invention Cycle**

*RESEARCH*

*TEST*

*DESIGN*

*PROTOTYPE*

*Lab-made lava lamp separated into its two layers after sitting out overnight.*
Our lava lamps were more cost effective, safer for the environment and people, and equally effective at creating a heterogenous mixture with two layers having differing viscosity. We caused a chemical reaction by mixing various substances that produced CO₂.

In this meeting, you are going to reexamine your lab-made lava lamp and explore how you can change the lava lamp’s life cycle. When traditional inventions are done with their useful life, they tend to become waste, either going to landfills, or worse, becoming toxic waste. Since all of our materials are benign and we thought about sustainability at the inception of our lava lamps, we know they break down safely.

There is so much more to learn about what these reagents can do! Let’s explore the reagents in different environments to see what reaction is caused. You will dissect your lab-made lava lamp in Lab A to determine what the starting materials are in each solution. Afterward, in Lab B, you will test both diluted and undiluted solutions in three different environments (filtration, evaporation, and extraction). You will explore these components by treating them as reagents and testing them in the various environments to determine if a product can be formed.

**LAB PREPARATIONS**

Roles for today’s lab:

Formulator (Name): _____________________________________________

Talker (Name): __________________________________________________

Doodler (Name): ________________________________________________

Organizer (Name): ______________________________________________

As a group, decide who will be in each role today. Remember that you can take other roles in upcoming labs. Suggested roles and responsibilities are:

**Formulator**—responsible for chemicals

**Talker**—responsible for reading the procedure and communicating results

**Doodler**—responsible for recording observations

**Organizer**—responsible for setting up all non-chemical materials and for cleaning up glassware
Before you begin, review the following safety rules as a class.

SAFETY

1. Students and educators should wear gloves and goggles during labs from pre-lab setup to post-lab cleanup.
2. The bottles used with this lab are labeled “Lab Only.” They should not be used for drinking purposes.
3. Be extra careful when using the hot plate.
4. Use heat-resistant gloves when handling the hot glassware.
5. Place warm glassware on the aluminum tray if the surface is not a lab bench.
6. Remember to turn off hot plates and all other heating devices after use.
7. Pour all components over a tray.

REMINDEERS

- Read through the lab before dissecting the lava lamp.
- Organize all of the materials you will use at your lab bench or station.
- The ingredients you used to make a lava lamp in Meeting 2 were: water, vinegar, food coloring, guar gum, baking soda, and oil.
LAB A: DISSECT AND IDENTIFY

Separation 1:
1. Pour the top layer of your settled lava lamp into Beaker 1. Remember to always pour over the tray.
2. Pour the bottom layer (remainder of the lava lamp) into the squeeze bottle and cap it.
3. Discard the contents of Beaker 1 as directed by your instructor. Then wash and dry it. You’ll use it again in Lab B.

<table>
<thead>
<tr>
<th>Identify Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lava lamp</td>
</tr>
<tr>
<td>Beaker 1</td>
</tr>
<tr>
<td>Squeeze bottle</td>
</tr>
</tbody>
</table>

Separation 2:
1. Flip the capped bottle upside down and let it settle into layers.
2. Label a second clean beaker “Undiluted” using the wax pencil.
3. Uncap the upside-down bottle over the “Undiluted” beaker and squeeze out the bottom layer.
4. Label a third clean beaker “Diluted” using the wax pencil.
5. Squeeze out the remainder of the fluid into the “Diluted” beaker.
6. Add 100 mL of tap water to the “Diluted” beaker to create a diluted solution.
LAB B: EXPERIMENT AND TEST WITH DILUTED AND UNDILUTED SOLUTIONS

Evaporation

1. Label clean and dry beakers with “D” and “U” using the wax pencil.

2. Pour 30 mL from the “Diluted” and “Undiluted” beakers into their matching “D” and “U” beakers.

3. Your instructor should be present while you learn how to operate the hot plate. When your instructor joins you at your station, turn on the hot plate and set to warm.

4. Hand the “D” and “U” beakers to your educator to place on the hot plate. It will take 6 to 8 minutes for the solution to solidify.

5. Turn off the hot plate after the solution solidifies.

6. Wearing heat-resistant gloves, carefully move the “U” and “D” beakers from the hot plate to the lab bench to cool.

7. Observe and record your observations.

8. Let the beakers cool. Then empty, clean, and dry them for the filtration experiment.

<table>
<thead>
<tr>
<th></th>
<th>Diluted Solution</th>
<th>Undiluted Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Could this be useful?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SAFETY

1. Use extra care when using the hot plate.

2. Remember to turn off hot plates and all other heating devices after use!
**Filtration**

1. Fold the filter papers to fit the funnels. Wet the filter papers with water. Let excess water drain out.

2. Set the funnels over the two clean beakers (“D” and “U”). Pour 30 mL of each solution into the funnel over the matching beaker.

3. Observe and record observations.

4. Empty, clean, and dry the beakers for the Extraction experiment.

<table>
<thead>
<tr>
<th></th>
<th>Diluted Solution</th>
<th>Undiluted Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Could this be useful?</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Fitting the filter paper requires you to fold the filter paper in half and then in half again. You will then cut it to fit into the funnel. Next, wet the filter paper with water so it adheres to the sides of the funnel.*
Extraction

1. Pour 15 mL of each solution into the matching beakers.

2. Add 15 mL of alcohol to the top of each of the beakers. Pour onto the stirring rod to keep the alcohol from breaking the surface of the solution.

3. Use a wire hook or unfolded paper clip to pass through the top layer of solution “U” and dip into the top of the bottom layer. Hook the surface of the bottom layer and pull upward.

4. Observe and record observations.

5. Repeat with solution “D.”

<table>
<thead>
<tr>
<th>Observation</th>
<th>Diluted Solution</th>
<th>Undiluted Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could this be useful?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nylon was invented using an extraction technique. Wallace Hume Carothers and a team of chemists with the du Pont Company invented the synthetic material in 1939. The team had been working on polymers. Nylon was marketed to the public in 1940 as hosiery for women. Nylon replaced the high-priced silk and hosiery became known as “Nylons.” Soon thereafter, du Pont produced nylon for many markets during World War II, including parachutes and mosquito nets. Today, nylon is used in a multitude of products including toys, fishing line, and medical devices.
POST-LAB CLEANUP

- All materials are safe to pour down the drain.
- Have students wipe any oil residue with a paper towel before washing the labware.
- Clean beakers, teaspoons, and stirring rods in a warm, soapy water bath with 30 mL of vinegar.
- Dry the tools and lab equipment, then store them properly in an educator-designated area.

EXTEND THE LEARNING

Alcohols often have -ol at the end of their names. In this lab we used Ethanol; in the next meeting we will use Sorbitol. Other alcohols that are also plasticizers include glycerol and mannitol.

What differences did you observe between the diluted and undiluted solutions?

__________________________________________________________
___________________________________________________________

What conclusions can you draw about the amount of water in the solutions and the properties of the plastic?

______________________________________________________________
______________________________________________________________

How does the rate of heating or evaporating in our samples impact the properties of the plastic?

______________________________________________________________
______________________________________________________________
REFLECTION: WHO KNEW?

Your first reaction may be that nothing useful was produced. Remember, when we invent, we must look at what we perceive as failed trials and explore the results. Could we have accidentally made something without being able to recognize it? What you probably didn’t know is that a chemical reaction happens when a starch, like guar gum, is heated in the presence of an acid, like acetic acid in vinegar. The chemical reaction produces a plastic. It would be hard to recognize this if you’ve never studied plastics. Plastics are defined by their properties, not by their materials. To be a plastic, a material must be able to mold into shape when soft and then set into a rigid or slightly elastic form.

Additionally, the alcohol layering on the undiluted solution should have produced a thin string. This, in fact, is how nylon is made. The alcohol dehydrates the solution to create a plastic with different properties. In fact, plasticizers, or materials that promote plasticity and flexibility, are often alcohols.

In our next meeting, we’ll explore the many roles of plastics in our lives and see if we can make a replacement plastic. Traditional plastics may take 1,000 years to degrade, while one made of these natural sources would be able to break down in weeks. Let’s try to make a greener plastic based on safety, cost, and performance.

SELF-ASSESSMENTS

Please turn in your completed self-assessment as an exit slip when you leave.

INDICATORS OF A SUCCESSFUL MEETING

You can evaporate, filter, and extract materials from solutions. You can form a bioplastic and understand the importance of the source of materials in a product’s life cycle.
KEY TERMS

Acid (n): a molecule that can donate a proton or accept an electron pair in reactions.

Alcohol (n): any organic compound whose molecule contains one or more hydroxyl groups attached to a carbon atom.

Bioplastic (n): a biodegradable plastic made from biological substances instead of petroleum.

Biological material (n): matter that has come from a once-living organism.

Crude oil (n): unrefined petroleum.

Tools and Lab Equipment

- 250-mL beakers, 3 per student group
- Aluminum tray, 1 per student group
- Heat-resistant gloves, 1 pair per student group
- Hot plate, 1 per student group
- Stirring rod, 1 per student group
- Syringes, 1 per student group
- Teaspoon (tsp.) measure, 1 per student group

Materials and Lab Supplies

- Wax pencil, 1 per student group
- Timer, 1 per student group
- Protective gloves, 1 pair per student
- Protective goggles, 1 per student
- Photocopies of Tracing Loops sheet, 1 per student
- Tapioca starch
- White vinegar
- Sorbitol
- Wax paper
- Tape
- Student Guides
**Procedure**

This meeting will cover:

- Plastics in our World
- Pre-Lab: What’s a **Bioplastic**?
- Lab Preparation
- Lab: Experimenting with **Bioplastics**
- Post-Lab Cleanup
- Reflection: **Bioplastic** Properties
- Journal Log
- Self-Assessments
- Indicators of a Successful Meeting

**Plastics in our World**

Take a plastics inventory in your classroom or lab. Look on desks and lab benches, look at the AV equipment, and even look in your backpack. What about your clothing—do you see any plastics?

1. How many plastic objects can you write here within five minutes?

2. Share your observations with your group.

3. Why do you think plastics were used in these products?

   ________________________________________________________________________
   ________________________________________________________________________
   ________________________________________________________________________

Chances are that most of the plastics you have identified are petroleum-based. Read about the life cycle of these plastics and highlight all the stages of the life cycle that could be improved upon to make the process more sustainable for the health of humans and the environment.

**Replicate (v):** to copy or repeat something.

**Starch (n):** an odorless, tasteless white substance naturally occurring in plant tissue; it stores carbohydrates.

**Wastewater (n):** water that is not clean because it has already been used in homes, businesses, factories, etc.

**STUDENT NOTE**

To get an idea of how many plastics are used in a minute, watch **Drowning in Plastic**.

Examples of plastics formed in different ways include plastic bags, which would be blown, and water bottles, which would be injected.
Petroleum-based plastic is made from **crude oil**, a nonrenewable resource. **Crude oil** is obtained by drilling into vast underground reservoirs. To extract the **crude oil**, a large amount of clean water is used, generating unusable wastewater. A large infrastructure is built to get the oil to ground level. Once there, the oil is pumped through a pipeline; these pipelines are sometimes thousands of miles long. The production and transportation of oil through these pipelines have two major risks—pipeline leaks and oil spills—which cause immediate and long-term environmental damage. The **crude oil** then goes to a refinery to be processed into different types of fuel and chemicals. The chemicals are further processed into polymers and into small plastic pellets. Additives are mixed in, more water is used, and strong **acids** are added to break down the pellets; these processes all contribute to additional risks in the production of plastic. Finally, the pellets are heated at high temperatures in a furnace. Once melted, the material is poured, blown, or injected into a mold and left to harden into its final plastic form. While many petroleum-based plastics are recyclable, a vast majority of them end up in landfills or in the ocean. These plastics last in the environment for approximately 400 years, on average. An overwhelming 93% of all plastics consumed in the United States are not recycled.

**The lifeline of petroleum plastic**

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**EXTEND THE LEARNING**

The field of **bioplastics** is vast and many scientists are inventing alternatives to petroleum-based plastics. Scientists are looking at how bees make honey in order to invent waterproof jackets, and Apple® is using **bioplastic** for the cover glass frames in their iPhone Xs. Many new companies are discovering breakthrough ideas by inventing with **bioplastics**. Loliware™ is one of these companies. They have invented a straw made of only **bioplastic**.
Pre-Lab: What’s a Bioplastic?

Looking at the life cycle, you can see that petroleum oil is extracted from the ground and may think to yourself, “If it comes from nature, shouldn’t that make it sustainable?”

Petroleum oil comes from deep in the ground and takes tens of millions of years to create, but humans consume oil at a much faster rate than it is made. The process of extracting oil from the ground also involves generating a lot of wastewater, and digging into the earth to extract the petroleum oil can disrupt the natural ecosystems.

The life cycle of bioplastic

Biological material, or living materials, can be grown and harvested above ground. This makes biological material more accessible, and they have a smaller environmental impact. Many companies have used biological material sources to make plastics to be more cost effective and sustainable than traditional petroleum oil-based plastics.
Depending on where you are in the world, different starches are used as the bios in bioplastics. You previously used guar gum as your starch material. In this lab, you will use tapioca starch as your starch material, instead of guar gum. Tapioca starch is understudied in the bioplastic field, which gives you a lot of opportunities to discover novel formations for creating new products.

**EXTEND THE LEARNING**

Scientists tend to use the bio source that is most abundant in their geographical region. Why would this matter when thinking about practicing green chemistry? These scientists are able to use machinery to change the bio source into whatever size they desire. What region would be using what type of starch?

We will now create bioplastics with our starch, alcohol, and additive. These are the three components to making a bioplastic. To optimize our bioplastic-making process, we will create six uniform loops using our syringe and a formulation with tapioca starch, white vinegar, and sorbitol.

**Making Bioplastics**

- **starch**: 2 tsp + additive 1 tsp
- **water**: 2 tsp
- **plasticizer**: 2 tsp
- **mix**
- **product**
As a group, decide who will be in each role today. Remember that you can take other roles in upcoming labs. Suggested roles and responsibilities are:

**Formulator**—responsible for chemicals

**Talker**—responsible for reading the procedure and communicating results

**Doodler**—responsible for recording observations

**Organizer**—responsible for setting up all non-chemical materials and for cleaning up glassware

**LAB PREPARATIONS**

Roles for today’s lab:

Formulator (Name): _______________________

Talker (Name): ____________________________

Doodler (Name): ___________________________

Organizer (Name): _________________________

Before you begin, review the following safety rules as a class.

**REMINDEES**

- Tell students to read through the lab before beginning.
- Have students organize all of the materials they will use at their lab bench or station.

**SAFETY**

1. Students and educators should wear gloves and goggles during labs from pre-lab setup to post-lab cleanup.

2. The bottles used with this lab are labeled “Lab Only.” They should not be used for drinking purposes.

3. Be extra careful when using the hot plate.

4. Use heat-resistant gloves when handling the hot glassware.

5. Place warm glassware on the aluminum tray if the surface is not a lab bench.

6. Remember to turn off hot plates and all other heating devices after use.

7. Pour all components over a tray.

Remember that the person handling the beaker must wear heat-resistant gloves.

Keep stirring the solution on the hot plate just until it thickens to a gel-like consistency. Heating the solution for too long can cause the plastic to
LAB: EXPERIMENTING WITH BIOPLASTICS

Use the following procedure to create a bioplastic product:

1. Place wax paper over your Tracing Loops sheet and tape it to the tabletop.

2. In a 250-mL beaker, use a teaspoon to measure 2 tsp. of tapioca starch and 1 tsp. of white vinegar. Mix with the stirring rod.

3. Measure 2 tsp. of water and add to your beaker. Mix with the stirring rod.

4. Measure 2 tsp. of sorbitol and add to your beaker. Mix with the stirring rod.

5. Stir the solution until uniform.

6. Turn on the hot plate and set to medium. Using a timer, heat the solution for 6–10 minutes, stirring for 15 seconds every minute until the solution starts to thicken.

7. When the solution reaches a gel-like consistency, turn off the hot plate and remove the beaker from the heat.

8. Using your stirring rod, transfer the material from the beaker into the syringe.

9. Push the material as close to the end as you can.

10. Insert the plunger and flip the syringe upward.

11. Push out excess air.

12. Trace the loops on the tracing sheet using your syringe.

13. Steps 2–12 can be repeated twice more, if time allows.

14. Let your bioplastic material sit overnight to form.
Students measuring tapioca starch to create their bioplastic material.

A student modeling how to use a syringe to complete the Tracing Loops sheet.
TRACING LOOPS

1. Fill syringe
2. Push out extra air
3. Pipe onto this sheet
MEETING 4

Students heating their solution while stirring for 15 seconds every minute.

POST-LAB CLEANUP

▶ All materials are safe to pour down the drain.
▶ Wipe any residue with a paper towel before washing the labware.
▶ Clean beakers, teaspoons, and stirring rods in a warm, soapy water bath with 30 mL of vinegar.
▶ Dry the tools and lab equipment, then store them properly in an educator-designated area.

REFLECTION: BIOPLASTIC PROPERTIES

Why did we make six identical loops? Scientists often make many samples, or replicates, of trials to find the best way to do something. This allows them to do material testing, or compare the properties of the samples, afterwards. In your group, identify what properties would be ideal for your bioplastic. Think about possible products your group could make with these properties.

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<tr>
<th>Structure:</th>
<th>Transparency:</th>
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GC_S_060820
SELF-ASSESSMENTS

Please turn in your completed self-assessment as an exit slip when you leave.

INDICATORS OF A SUCCESSFUL MEETING

You were able to set up multiple experiments to make a bioplastic. You can identify why bioplastics are more sustainable than petroleum-based plastics. You understand why there is a need to invent new sustainable solutions. Experiments, formulas, and observed results are accurately described in your Log and can be used to make optimization decisions.

EXTEND THE LEARNING

Think back to the plastics identified in the beginning of the meeting. Could any of these be replaced with bioplastics?

How long should we plan for these products to remain in use?

Similarly, how long should we plan for them to last until they biodegrade?

Compare the stages of the life cycle of bioplastics with the life line of traditional plastics. Notice that one is a cycle, while the other is in a line. What does this tell you about their life cycles? Use the key terms to help cover key components.
KEY TERMS

**Acidity (n):** the amount of acid in a substance.

**Cross-link (n):** A chemical bond of one polymer chain to another.

**Molecule (n):** a group of atoms that are bonded together and make up the smallest unit of a chemical compound.

**Monomer (n):** a molecule that can be bonded to other like molecules to form a long-chain polymer.

**Optimize (v):** to make a material as effective or functional as possible.

---

**Tools and Lab Equipment**

- 250-mL beakers, 3 per student group
- Aluminum tray, 1 per student group
- Heat-resistant gloves, 1 pair per student group
- Hot plate, 1 per student group
- Stirring rod, 1 per student group
- Syringes, 1 per student group
- Teaspoon (tsp.) measure, 1 per student group

**Materials and Lab Supplies**

- Wax pencil, 1 per student group
- Timer, 1 per student group
- Protective gloves, 1 pair per student
- Protective goggles, 1 per student
- Wax paper
- Tape
- Additives: White vinegar, baking soda
- Coconut oil
- Cookie cutter molds (various designs)
- Sorbitol
- Tapioca starch
- Tracing Loops Sheet
- Your Student Guide
**Procedure**

This meeting will cover:.

- Pre-Lab: Method for Optimizing
- Safety
- Lab: Optimize Formulations
- Post-Lab Cleanup
- Reflection: What to make?
- Journal Log
- Self-Assessments
- Indicators of a Successful Meeting

**PRE-LAB: METHOD for OPTIMIZING**

Look back at your loops from the last meeting. Walk around to other groups’ stations and compare how your loops are similar or different. Remember to be careful when handling other groups’ samples.

Answer the following questions and then discuss as a class.

Do any of your loops have the properties your group wanted?

____________________________________________________________________________________

____________________________________________________________________________________

Do the loops of other groups look the way your group wanted? What qualities were they aiming to achieve and how did they achieve those qualities?

____________________________________________________________________________________

____________________________________________________________________________________

These loops varied because of different executions of the same procedure. But what if we purposely introduced new variables to cause different properties in our samples?

**pH (n):** a scale that expresses acidity (lower numbers) or alkalinity (higher numbers) of a solution on a logarithmic scale of 1–14, on which 7 is neutral.

**Polymer (n):** a substance whose molecular structure is made up of large numbers of similar units (monomers) that are bonded together.

**Variable (n):** something that can change, especially in a way that cannot be known in advance.
The bioplastic properties are determined by two factors: 1) the concentration of the solution, and 2) the acidity or basicity of the solution.

**CONCENTRATION**

The bioplastic properties are determined in part by how much water is in the solution. If more water is added into the solution, the solution becomes more dilute, or less concentrated. The more water in the solution, the more flexible the final product.

**ACIDS AND BASES**

Plastics come in many shapes and forms, and their properties change based on the chemical reactions that occur when they are created. Our starting material, starch, is a **polymer**, or long chain, of sugars. The polymer chains of sugars interact with each other through bonding, or **cross-linking**. Lots of bonds between the chains create a rigid structure, while less bonds between the chains create a loose and flexible structure.

**pH**, or how acidic or basic an environment is, impacts how much bonding (cross-linking) occurs. A strong acid or base blocks some cross-linking when creating your bioplastic. Putting your starch polymer in a weak acid or base environment will keep more of the cross-linking bonds intact, and create a more rigid product.
**pH** is an important factor when conducting chemical reactions. The **pH** of a solution is a measure of the acidity or basicity of the solution. Stronger acids or bases create smaller pieces, or smaller **polymers**. The plasticizer and heat rebind the smaller pieces into moldable, long-chain **polymers**.

One can tell how strong an acid or base is by how far it is from 7 on the **pH** scale. The scale ranges from 1 (strong acid) to 7 (neutral) to 14 (strong base). Today, you will choose the strength of the acid or base your group will use. This will change the properties of your products.

**STUDENT NOTE**

If you want more information about variables within your bioplastic creations, refer to the Reference sheet from Meeting 1. This will provide you with information on granule sizes of different starches and how that changes your material’s surface area. The Reference sheet also provides information on the effect of **pH** on your solution. If your educator allows, you can introduce other household additives to change the **pH** of your solution.

**EXTEND THE LEARNING**

Predict what the strength of your acid will do to your product.

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________________________________________________________________________
Today, you will do a material test with your own bioplastic formulation. You will later decide how to use your bioplastics in a new and innovative way. Please consider whether your design would benefit from using loops or using cookie cutters. Discuss and write down the benefits of both and come to a decision as a group.

<table>
<thead>
<tr>
<th>Loops</th>
<th>Cookie Cutters</th>
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<tr>
<td>1.</td>
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**LAB PREPARATIONS**

Roles for today’s lab:

Formulator (Name): _____________________________________________

Talker (Name): __________________________________________________

Doodler (Name): _______________________________________________

Organizer (Name): ______________________________________________

In 2015, the LEGO Group announced that it would invest in research and development to search for sustainable materials as alternatives for current materials used in bricks and packaging. The company announced plans to hire employees specifically for a new Sustainable Materials Center. The company committed to first tackle its packaging, with aims for no product packaging to end up in a landfill after 2025. Additionally, the LEGO Group announced that it had started producing LEGO® botanical elements in 2018 that are made from plant-based polyethylene plastic sourced from sugarcane.
REMINDERS

► Tell students to read through the lab before dissecting the lava lamp.
► Have students organize all of the materials they will use at their lab bench or station.

LAB ROLES

As a group, decide who will be in each role today. Remember that you can take other roles in upcoming labs. Suggested roles and responsibilities are:

Formulator—responsible for chemicals
Talker—responsible for reading the procedure and communicating results
Doodler—responsible for recording observations
Organizer—responsible for setting up all non-chemical materials and for cleaning up glassware

SAFETY

1. Students and educators should wear gloves and goggles during labs from pre-lab setup to post-lab cleanup.
2. The bottles used with this lab are labeled “Lab Only.” They should not be used for drinking purposes.
3. Be extra careful when using the hot plate.
4. Use heat-resistant gloves when handling the hot glassware.
5. Place warm glassware on the aluminum tray if the surface is not a lab bench.
6. Remember to turn off hot plates and all other heating devices after use.
7. Pour all components over a tray.

STUDENT NOTE

The person handling the beaker must wear heat-resistant gloves.
LAB: OPTIMIZE FORMULATION

Carefully follow these steps:

1. Tape wax paper onto the tabletop (over the Tracing Loops sheet, if using it). If using cookie cutters, cover them in coconut oil.

2. Use the wax pencil to label your beaker with the plasticizer, additive, and starch you will use.

3. In a 250-mL beaker, use a teaspoon to measure 2 tsp. of starch and 1 tsp. of your acid or base. Mix with the stirring rod.

4. Measure 2 tsp. of water and add to your beaker. Mix with the stirring rod.

5. Measure 2 tsp. of plasticizer and add to your beaker. Mix with the stirring rod.

6. Mix the solution until uniform.

7. Turn on the hot plate and set to medium. Using a timer, heat the solution for 6–10 minutes, stirring for 15 seconds every minute until the solution starts to thicken.

8. When the solution reaches a gel-like consistency, turn off the hot plate and remove the beaker from the heat.

9. Using your stirring rod, transfer the material from the beaker into the syringe.

10. Push the material as close to the end as possible.

11. Insert the plunger and flip the syringe upward.

12. Push out excess air.

13. Use the syringe to either fill a cookie cutter or make a loop.

14. Let your bioplastic material sit overnight to form.

15. Steps 2–14 can be repeated twice more with a clean beaker, if time allows.
**OPTIMIZE BIOPLASTICS**

**Formulation**

Starch 2 tsp +
+ Additive 1 tsp

Mix

Water 2 tsp

Mix

Plasticizer 2 tsp

Mix

Product

**Goals for Prototype:**

**Materials**

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<thead>
<tr>
<th>Starch</th>
<th>Additive</th>
<th>Plasticizer</th>
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<tr>
<th>Starch</th>
<th>Additive</th>
<th>Plasticizer</th>
<th>Properties</th>
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POST-LAB CLEANUP

▶ All materials are safe to pour down the drain.
▶ Wipe any residue with a paper towel before washing the labware.
▶ Clean beakers, teaspoons, and stirring rods in a warm, soapy water bath with 30 mL of vinegar.
▶ Dry the tools and lab equipment, then store them properly in an educator-designated area.

REFLECTION: WHAT TO MAKE?

Is there one formulation that stands out from the others based on your group’s optimization trials?

How well did the formulation trials meet your group’s goals for your material?

It is now time to start thinking about what your group wants to make with your optimized formulations! Whether it be a figurine, emblem, or stamp, the finished prototype is only limited by the materials present and by size. Size constraints include that it must be smaller than half of a sheet of paper in order to diagram the dimensions within the notebook.

Sketch your bioplastic prototype ideas in your journal. Brainstorm what materials you need to create the mold that will form your bioplastic product. Refer to the Optimizing Bioplastics Procedure as you identify the materials you will need to shape and mold your bioplastic prototype.

Use the time between this meeting and the next one to brainstorm what you would like to make!
SELF-ASSESSMENTS

Please turn in your completed self-assessments as an exit slip when you leave.

INDICATORS OF A SUCCESSFUL MEETING

You can reflect on material properties and characteristics of the initial bioplastic trials. You can identify the materials needed to formulate an optimized bioplastic.

EXTEND THE LEARNING

Even with this understanding of how different factors change bioplastic properties, it is difficult to predict results. This is because there are still other variables to consider:

- Water interacts with the starch molecules to determine the viscosity of the solution.
- The surface area of the starch granules contributes to how much the water is able to interact with the starch molecules. Water can interact more with starch that has smaller granules, thus dissolving the starch easier.
- The type and size of the starch impacts chemical reactions.

Refer to the reference page on granule sizes of various starches. Predict what each starch would do to impact the bioplastic properties.

_________________________________________________________

_________________________________________________________

_________________________________________________________
KEY TERMS

Blueprint (n): a design plan or technical drawing. Before computer-aided design, prints of plans were photographed in white on a blue background. This is the reason for the name "blueprints."

Intellectual property (n): a creative work originated in a person’s mind that may be protected by law as patents (utility, design, plant) and trademarks by the U.S. Patent and Trademark Office and copyrights by the U.S. Copyright Office.

Product hook (n): a short phrase or jingle designed to entice consumers to purchase a product.

Tools and Lab Equipment
- Hot plate, 1 per student group
- Syringe, 1 per student group
- Aluminum tray, 1 per student group
- Heat-resistant gloves, 1 pair per student group
- 250-mL beaker, 1 per student group
- Protective gloves, 1 pair per student
- Protective goggles, 1 per student

Materials and Lab Supplies
- Wax pencil, 1 per student group
- Additives: white vinegar, baking soda
- Plasticizer: sorbitol
- Starches: tapioca, potato, corn
- Coconut oil
- Cookie cutter molds (various designs)
- Modeling clay
- Wax paper
- Your Student Guide
Procedure

This meeting will cover:

- Pre-Lab: Bioplastic Blueprint
- Lab: Creating Prototypes from a Blueprint
- Post-Lab Cleanup
- Write the Hook
- Reflection: Ready to Make Green!
- Journal Log
- Self-Assessments
- Indicators of a Successful Meeting

PRE-LAB: BIOPLASTIC BLUEPRINT

Look back at your samples and identify what you will make with your samples and their unique properties. It is now time to create a bioplastic prototype based on your group’s results from the “Optimizing Our Bioplastic Invention” lab. During this meeting, your group will have three tasks to complete: blueprinting, pitch writing, and prototype creation.

1. First, your group will complete the Bioplastic Blueprint sheet. You will draw a full-sized diagram of your bioplastic prototype and write the formulation for the bioplastic prototype. Look back at your samples and brainstorm as a group to identify what you will make with your samples. The Bioplastic Blueprint will be key as you enter the next phase.

By blueprinting your ideas, you can claim this idea as your own! In fact, many of the components of a patent are present in the blueprint sheet. Patents are important because they allow one to claim the intellectual property of an idea. A patent allows the inventor to prevent others from profiting from their ideas. Patenting a process or product may be important when there is a unique idea about how to do something in a safer, more sustainable way.
2. After your group completes the Bioplastic Blueprint sheet, you will move on to the lab to make a bioplastic prototype. Your bioplastic prototype will be the finalized bioplastic formulation molded into shape.

3. Finally, your group will consider the best way to communicate your invention—including the **product hook**—in preparation for the final meeting.

**STUDENT NOTE**

You should be able to make 2–3 loops per formulation.

**EXTEND THE LEARNING**

Patents provide detailed images of ideas before they become consumer products. Can you recognize the patent images for any of these products?

Goal: ____________________________________________________

Product: ________________________________________________

Properties: ______________________________________________

Materials:
__________________________________
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Procedure:
1. _____________________________________________________
2. _____________________________________________________
3. _____________________________________________________
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9. _____________________________________________________
10. _____________________________________________________
11. _____________________________________________________
12. _____________________________________________________
LAB PREPARATIONS

Roles for today’s lab:
Formulator (Name): _____________________________________________
Talker (Name): _________________________________________________
Doodler (Name): ________________________________________________
Organizer (Name) _______________________________________________

Before you begin, review the following safety rules as a class.

REMINDERS

- Read through the lab before beginning.
- Organize all of the materials you will use at your lab bench or station.
- The formulation for your bioplastic prototype is based on your group’s Bioplastic Blueprint sheet. It will be similar to the procedure from the previous trials of experimentation and optimization.
SAFETY

1. Students and educators should wear gloves and goggles during labs from pre-lab setup to post-lab cleanup.

2. The bottles used with this lab are labeled “Lab Only.” They should not be used for drinking purposes.

3. Be extra careful when using the hot plate.

4. Use heat-resistant gloves when handling the hot glassware.

5. Place warm glassware on the aluminum tray if the surface is not a lab bench.

6. Remember to turn off hot plates and all other heating devices after use.

7. Pour all components over a tray.

LAB: CREATING PROTOTYPES FROM A BLUEPRINT

Evaluate the results from your Optimizing Our Bioplastic Invention lab trials. This information will help you determine the final version of your bioplastic formulation.

4. Record the properties of the bioplastic, such as stickiness, hardness, brittleness, and flexibility.

________________________________________________
________________________________________________

5. Did the properties change over time? How?

________________________________________________
________________________________________________

6. Do the properties align with or differ from the group’s goals for a product?

________________________________________________
________________________________________________

STUDENT NOTE

The person handling the beaker must wear heat-resistant gloves.
The formulation for your bioplastic prototype is based on your group’s Bioplastic Blueprint sheet. It will be similar to the procedure from your previous trials of experimentation and optimization.

1. Fill in the Bioplastic Blueprint sheet with amounts and materials before you experiment.

2. Use the wax pencil to label your beaker with the plasticizer, additive, and starch you’ll use.

3. Tape wax paper onto the tabletop.

4. Select appropriate molds (cookie cutter forms) for your prototype shape or make your own out of clay.

5. Apply coconut oil to wax paper and to the molds (cookie cutter forms or clay). This will help with removing the bioplastic once it hardens.

6. In your 250-mL beaker, use a teaspoon to measure 2 tsp. of your starch and 1 tsp. of your acid or base. Mix with the stirring rod.

7. Measure 2 tsp. of water and add to your beaker. Mix with the stirring rod.

8. Measure 2 tsp. of your plasticizer and add to your beaker. Mix with the stirring rod.

9. Mix the solution until uniform.

10. Using the hot plate and a timer, heat the solution on medium heat for 6–10 minutes, stirring for 15 seconds every minute until it starts to thicken.

11. Using your stirring rod, transfer the material from the beaker into the syringe.

12. Push the material as close to the end as you can.

13. Insert the plunger and flip the syringe upward.

14. Push out excess air.

15. Using your syringe, transfer the material from the beaker into your desired form.

16. Let your bioplastic material sit overnight to form.

17. Label your bioplastic prototype and set it on the tray to store for the next meeting.
Green Chemistry inventing is challenging, but inventing allows us to constantly make tweaks and adjustments to our ideas through further optimization. With more time, you could create an even more effective green chemistry invention.
Student creating a bioplastic window cling.

Student group creating bioplastic walls to later use to build a prototype miniature house.
WRITE THE HOOK

During this invention process, the focus has been on green chemistry criteria and using benign materials in order to minimize cost and safety risk. The benefits of green chemistry-inspired inventing are clear. Also, consumers desire materials that are safer for human health and the environment. With this in mind, consider how you can promote your product to potential buyers. Communicating the value of a product is an important component of inventing. After all, a life-changing invention can only change lives if people want to buy it.

What makes your group’s ideas for the invention unique? What need does the invention fill? Answering these questions will help you develop the product hook and tell the invention’s story. It is important to be able to tell the invention’s story. Complete the Hook sheet with your group and try to incorporate how your group’s invention addresses the challenges of traditional plastics and offers a unique alternative to a known product.

REFLECTION: READY TO MAKE GREEN!

Congratulations on creating a prototype using an inventive bioplastic! Green chemistry invention is benign by design. This means that sustainability was considered during the entire inventing process.

Green chemistry inventions are judged based on three criteria: cost, safety, and performance. Think about what problem is being solved with this invention idea. What would it replace in today’s marketplace?

REFLECTION: READY TO MAKE GREEN!

Congratulations on creating a prototype using an inventive bioplastic! Green chemistry invention is benign by design. This means that sustainability was considered during the entire inventing process.

Green chemistry inventions are judged based on three criteria: cost, safety, and performance. Think about what problem is being solved with this invention idea. What would it replace in today’s marketplace?

SELF-ASSESSMENTS

Please turn in your completed self-assessment as an exit slip when you leave.

INDICATORS OF A SUCCESSFUL MEETING

You can design and blueprint a bioplastic prototype, make a bioplastic prototype, and craft the companion invention story.
1. Why did you choose to make your invention?

2. What does it do?

3. Why is it useful?

4. What problem does it solve?

5. Who would use it?

6. Does it replace an object?

7. What makes it appealing to a consumer?

8. What makes it useful to a consumer?

9. What tools are needed to make the product?

10. What materials are needed to make the product?

11. Estimated cost of inventing?

12. What is your product’s one-liner or hook to get a person interested in it?
Materials and Lab Supplies
▶ Your Student Guide

Procedure
This meeting will cover:
▶ Meet the Inventor: Maher Damak, Lemelson-MIT Student Prize Winner
▶ Real-World Bioplastic Invention: Ooho
▶ Invention Statement
▶ Communicating with the Hook
▶ End of Life: Design for Biodegradation
▶ Reflection: Inventing with Green Chemistry
▶ Journal Log
▶ Self-Assessments
▶ Indicators of a Successful Meeting

KEY TERMS

Biodegradation (n): the breakdown of material by microorganisms into natural substances.
Feedback (n): information received which can be used to improve something.
Formulate (v): to devise or develop; make.
Peer (n): one who is equal to you or belonging in the same group based on specific criteria such as age, schooling, or professional credentials.
Peer review (n): a process of evaluation of scientific, academic, or professional work by others working in the same field.
MEET THE INVENTOR: MAHER DAMAK, LEMELSON-MIT STUDENT PRIZE WINNER

Maher Damak received his PhD from the Department of Mechanical Engineering at the Massachusetts Institute of Technology (MIT). Science has always been one of Maher’s passions, including the rigor of mathematics embedded within science and the beauty of physics, which turns natural phenomena into equations. Upon taking his first thermodynamics and electromagnetism courses and learning that a simple set of equations can explain the greenhouse effect, why water freezes, and why the sky is blue, he was convinced that scientific research was the right path for him.

Maher studied interfacial phenomena and fluid mechanics with Associate Professor Kripa Varanasi serving as his advisor. He invented a new technology that enhances the ability of agricultural chemicals being sprayed on plants to stick to the plants as intended, instead of rolling off into the soil. The technology is formulated with polymers that are biocompatible and biodegradable so they will not cause any additional pollution or health hazards. Maher earned the 2018 $15,000 “Eat it!” Lemelson-MIT Student Prize for his inventive work.

In addition to his education, Maher values community and mentoring as part of his life. One of his most rewarding volunteer experiences was in an economically challenged neighborhood in the suburbs of Paris. He spent eight months there working for Asphalte, a nonprofit association committed to helping immigrants integrate into French society. Maher assisted the children with their education. His responsibilities included mentoring a group of at-risk youth, helping them with schoolwork, organizing review sessions on various subjects, and hosting interactive sessions in which they could express their opinions and engage in critical thinking.

Maher is excited to pursue an entrepreneurial path to bring his inventions to market. He has already co-founded a company, Infinite Cooling. His company will commercialize a water-recovery invention and bring greater efficiency to the way power plants use water. Maher’s invention will help to conserve this precious resource. As an entrepreneur, he plans to bring his technologies to those who need them, helping to mitigate some of the biggest problems that humanity faces in the 21st century.
One company working to reduce the number of plastic water bottles produced and consumed is Notpla. This is an innovative, sustainable packaging start-up company based in London. Ooho, the lab’s first product, aims to change the disposable water bottle market with alternative packaging for water. Ooho packaging is made from plants and seaweed and will biodegrade in just four to six weeks—the same time that it takes for a piece of fruit to biodegrade. This bioplastic invention claims to utilize nine times less energy and produces five times less carbon dioxide than polyethylene terephthalate (PET), which is currently used for plastic water bottles. Best of all, Ooho packaging is not just biodegradable, but also edible. This invention aligns with green chemistry-inspired invention by designing for degradation and addressing the end of the product’s life in the most sustainable way possible.

What a novel approach: to reduce traditional plastics in the environment through applying green chemistry in inventing! Check out Ooho’s product hook video.
Plastic bottle production continues to increase. One study, as reported by the American Society of Engineering Education, stated that the production of plastic bottles will be more than 500,000,000 tons by 2021. Most plastic bottles are made out of polyethylene terephthalate (PET), which is recyclable. Unfortunately, many tons of bottles are not recycled and still end up in landfills or polluting the environment.

A team of inventors at the National University of Singapore’s School of Engineering has found a way to turn plastic waste into a low-cost, lightweight PET aerogel that can be used for heat and sound insulation, oil spill clean-up, and as lightweight lining for firefighter coats. Are there ways to use green chemistry to plan for the use of recycled PET bottles?
Our JV InvenTeam green chemists are

_____________________________________________________________

_____________________________________________________________

The properties of the bioplastic include

_____________________________________________________________

_____________________________________________________________

It is useful for

_____________________________________________________________

(who is the user/consumer?)

because

_____________________________________________________________

_____________________________________________________________

(describe the need or problem)

It is unique because

_____________________________________________________________

_____________________________________________________________

(describe how it works or is different from other plastics)

The source materials we need to make our bioplastic are

___________________ __________________ __________________
The process needed to make the product for consumers is


This process requires these materials and additional inputs


The estimated total cost to make our invention into a consumer product is $ 


COMMUNICATING WITH THE HOOK

Being able to communicate with each other is important for sharing ideas. If someone cannot explain something clearly and succinctly, whether it be a story or an invention, the idea will not be understood.

Scientists work hard to communicate what they invent. Often, inventions and their underlying science are extremely complex and cannot be seen by the naked eye. Therefore, it is important for scientists to develop communication skills so they can share what they are doing in a way that the general public can understand the invention and discovery.

Inventing bioplastic solutions using green chemistry is both important and extremely complex. Bioplastics offer unique properties that allow products to be made from them. The bioplastic product can then be described to consumers. What is the best “hook” for consumers to learn about—and to consider buying—a product made using the principles of green chemistry?
Use the Invention Statement worksheet and your Hook sheet to prepare ways of communicating with others at the bioplastic prototype showcase. This is a type of communication, between technology and science, that often involves marketing and advertising. The hook will describe your invention to people who don’t know about your product. It uses aspects of the Invention Statement and Hook sheets and incorporates green chemistry principles.

1. Refer back to the Hook sheet you completed in Meeting 6.

2. Work with your group to rewrite answers to the guiding questions in one succinct paragraph.

3. You should memorize the paragraph for quick and accurate descriptions of the product when you are asked about it.

4. Practice reciting your hook with peer reviews. Share your hook with peers and ask for feedback to ensure your hook is clear and understandable.

5. Consider other communications skills in addition to the verbal message. Communication skills and delivery of the verbal message improve with practice. Practice builds confidence. Keep in mind that your “body language” is also a skill to be developed. Body language supports the message delivered in the hook. Remember, effective communicators always:

   • Stand up straight,
   • Minimize hand gestures and body movements,
   • Make eye contact,
   • Shake hands with a firm grip, and
   • Smile!

Student bioplastic creations including a heart stamp, teddy bear figurine, and a duck window cling.
END OF LIFE: DESIGN FOR BIODEGRADATION

Green chemistry invention addresses a product’s end of life through every stage of inventing. You selected natural sources for your bioplastics and intentionally created materials that will biodegrade. Therefore, you have designed bioplastic prototypes that incorporate a plan for when the products cease to be functional and reach the end of their lives.

New materials—like bioplastics—are always being developed. Scientists, engineers, and inventors can have an impact on the environment when they create new materials and products. Green chemistry seeks to minimize negative impacts on the environment by introducing sustainable materials across industries. The bioplastics industry is just one of the fields utilizing green chemistry successfully. The global bioplastics market is expected to see 40% growth in production by 2030, reaching $324 billion in sales. This means that there are a lot of career opportunities in pursuing the scientific fields of chemistry, material science, and engineering.

The world of green chemistry is not limited to the lab, but overlaps with many other disciplines. It makes a difference if you support sustainable companies with your purchases and if you use your voice to share important ideas.
EXTEND THE LEARNING

Did you know that the waste from shrimp, crab, and lobster shells is estimated to be six to eight million tons? Community college student, Jacob Couch, found this fact astounding. He put this into perspective. One ton, or 2,000 pounds, is equivalent to the weight of a polar bear or a sub-compact car. That’s a lot of waste to throw away. Now, imagine keeping all of that waste out of landfills by turning the chemical components in the shells into something useful.

A group of students from the Royal College of Arts and Imperial College London in the United Kingdom experimented with one of the major shell components, chitin. Chitin is a nitrogen-rich biopolymer. It is one of the most abundant organic compounds on earth. It is also biodegradable. The college students designed machines that can make biodegradable and sustainable products out of chitosan, the active ingredient in chitin. Liquid chitosan can be molded or formed and dried to make packaging, containers, and sheets. Jacob remarked, “These students’ inventions show that it is possible to create new and novel solutions by reusing waste. This new solution can help us get rid of single-use plastics that plague our environment.”
**REFLECTION: INVENTING WITH GREEN CHEMISTRY**

Use the last Journal Log for self-reflection on the green chemistry process, individual and group contributions to the JV InvenTeam, chemistry learnings, and ways of thinking like an inventor.

1. What ways of thinking and inventing have you developed in JV InvenTeams?

______________________________________________________________

______________________________________________________________

2. What skills and knowledge need further development?

______________________________________________________________
1. What are some of your green chemistry goals for the future?

____________________________________________________________________

____________________________________________________________________

SELF-ASSESSMENTS

Please turn in your completed self-assessment as an exit slip when you leave.

INDICATORS OF A SUCCESSFUL MEETING

As a group, you can create a display that includes your prototype, invention statement, drawings, and Journal Logs to support...
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