NATIONAL PEER REVIEWED

MODULE 2

GRADES 3-5

Sustainable Polymers

Plastics of the Future for a Green, Clean World

A 4-H STEM Curriculum for Grades 3-5 | 4hpolymers.org

National Science Foundation | NSF Center for Sustainable Polymers

4-H Polymer Science Curriculum for

Grades 3-5

4hpolymers.org

The themes of these modules touch on the prevalence and impact of plastics in everyday life. Plastics are versatile materials that come in different shapes, sizes, and exhibit different material properties. Scientists and engineers are working on new ways to create, use, and recycle plastics, so we can use plastics for their many advantages and lessen their effects on our environment.

Each module will include "Tips for Facilitators" and the Science and Engineering Practices, as well as opportunities to use "I Wonder" Boards, science journals, and math. In addition, these modules incorporate the SciGirls Strategies for gender equitable STEM learning. We encourage instructors to collect feedback throughout this module and submit via this evaluation form: 4hpolymers.org/evaluation.

National Science Foundation

NSF Center for Sustainable Polymers

Tips and Callouts

"I Wonder" Boards

These boards should be used to track children's questions and ideas during the lesson for further investigation. This tool promotes experimental learning by youth while encouraging curiosity and discovery. Basic "I Wonder" Boards have "I Wonder..." written at the top of a large sheet or white board.

Science Journals

Journals help youth keep track of what they've noticed and learned during the activities. Journals promote a science identity and allow youth to reflect on their thoughts and feelings. For children who are unable to write, drawing pictures is a good substitute.

Using Math

Providing youth opportunities to use math and numbers is important for developing their math skills at a young age. Math is important to science because it allows definitive answers to be found and can help youth find out if something has changed.

Science and Engineering Practices

The Next Generation Science Standards (NGSS) identifies eight practices of science and engineering that are essential for all students to learn. Using these practices, youth make sense of phenomena and use these skills to investigate the world and design and build systems.

SciGirls Strategies

Based on educational research, the SciGirls Strategies are used to target and engage girls in STEM learning, but have also been proven to work with all learners, including underrepresented youth. See the SciGirls Strategies handout at the back of the module for a more detailed explanation.

Module 2

Materials Matter

PRIMARY AUTHOR: ANNE STEVENSON
CONTRIBUTING AUTHORS: AMIE MONDL, KELLY STREI

Introduction

MODULE SUMMARY

Youth explore materials and their properties, and explore the concepts of monomer, polymer, and molecule. Youth investigate how chains of molecules that make up polymers and plastics affect the function of an object, and conduct a test to see how heat affects different types of plastics. Youth discover the wide range of functions of polymers and consider some of the benefits and challenges of this material.

Total lesson time needed for Module 2: 65-90 minutes not including set up time
Getting Ready: 35-45 minutes total

- Activity A: Cup Wars (15-20 minutes)
- Activity B: What's the Science Behind Cup Wars? (15-20 minutes)
- Activity C: Polymers – One Type of Material (10-15 minutes)
- Activity D: A Stop at the QuickShop Store (15-20 minutes)
- Reflection/Wrap Up (10-15 minutes)

Total estimated time for Module 2: **100-135** minutes, including set up time

Module Focus

LEARNING OBJECTIVES	• Youth will understand that materials (and all matter) are made of smaller building blocks (particles) that are too small to see • Youth will discover that polymers are long chains of repeating units • Youth will explore how materials & their properties influence their function or purpose
SCIENCE AND ENGINEERING PRACTICES *Youth will engage in the following NGSS Practices:*	• Developing and using models • Asking questions • Analyzing and interpreting data • Constructing explanations (for science) and designing solutions (for engineering) • Engaging in argument from evidence
CONCEPTS & VOCABULARY	• **Atom:** the basic unit of a chemical element; the smallest component of an element • **Function:** the purpose of an object or what it is used for • **Material:** a physical substance of which something is made or can be made; wood, plastics, glass, and metal are some examples of materials • **Matter:** Anything that takes up space is called matter. (Air, water, rocks, and even people are examples of matter); matter can exist in one of three main states: solid, liquid, or gas *Continued on next page*

Module Focus (Continued)

CONCEPTS AND VOCABULARY CONT.

- **Molecule:** the smallest unit of a substance that has all the properties of that substance; made up of two or more atoms
- **Monomer:** a part or single unit (‘mono’ means one and ‘mer’ means unit)
- **Natural Polymer:** a type of polymer that comes from nature
- **Polymer:** large molecule made of long chains of repeating parts. Each repeating unit is the “monomer,” so polymer=many repeating units
- **Properties:** characteristics that can be observed or measured; properties include size, shape, density, texture, hardness, color, odor, and other ways something looks or feels
- **Synthetic Polymer:** a type of polymer made up of chemical compounds discovered by scientists; “human-made” rather than occurring in nature

Facilitator Preparation

MATERIALS - ACTIVITY A – CUP WARS

- ☐ One PLA cup (identified as Sample A) - 1 per group of three youth
- ☐ One PS cup (identified as Sample B) - 1 per group of three youth
- ☐ One other plastic cup (identified as Sample C) - 1 per group of three youth
- ☐ Permanent marker, black or blue - 2-3
- ☐ Blow dryer - 2-3
- ☐ Cup Wars Data sheet-Appendix A - 1 per group
- ☐ Pens/pencils - 1 per group

Note: Sample A is made of polylactide (also called poly lactic acid, and should say PLA on the bottom of the cup); Sample B is made of polystyrene and will say PS on the bottom. (e.g. white styrofoam cup) Provide one additional type of plastic cup (Sample C), such as Solo™ cups, Dixie™ cups, or any other plastic or paper beverage cup

GETTING READY (10-15 MINUTES)

- Use a permanent marker to label cup samples with A, B, or C on the bottom
- Set up equipment (hair dryers, cups); for larger group you may wish to set up three stations (one for testing Cup A, one for B & one for C), and have youth rotate through the stations to conduct their tests
- Test sample C prior to the lesson, using the hair dryer test, so you know what will happen; for example, a Solo ™ brand cup may show some melting; heating a Dixie ™ brand, wax-covered paper cup may cause the wax to soften and become warm; other cups will vary so facilitator should test before using
- Put youth in groups of three **5**

5 SciGirls

STEM is collaborative, social, and community-oriented

Facilitator Preparation (Continued)

MATERIALS - ACTIVITY B – CUP WAR SCIENCE

- ☐ Bandanas, 12-15 (or strips of cloth approximately 12” x 4” if bandanas aren’t available)

GETTING READY (5 MINUTES)

- Gather supplies listed under the materials list

MATERIALS - ACTIVITY C – POLYMERS – ONE TYPE OF MATERIAL

- ☐ A variety of common plastic items: rubber bands, bouncy ball, tiny rubber Lego tires, a football, CD case, styrofoam pool noodle or cup, fleece jacket, nylon fabric, rubber spatula, a plastic bag, plastic cup, a bio-plastic cup
- ☐ Alternate option, if unable to gather items, is to print off Appendix B photo cards

GETTING READY (10-15 MINUTES)

- Gather supplies listed under the materials list
- If needed, print Appendix B photo cards

MATERIALS - ACTIVITY D - STOP AT THE QUICKSHOP STORE

- ☐ Print copies of Appendix C
- ☐ Small stickers for voting, 1 per youth
- ☐ Chart paper

GETTING READY (10 MINUTES)

- Gather supplies listed under the materials list
- Print copies of Appendix C

Background Information for the Facilitator

Polymers are in almost everything we use in our everyday life. A polymer is a large molecule made up of long chains of repeating units. Each unit, or repeating part, is a monomer. The word 'mer' means unit, and 'mono' means one.

A **molecule** is the smallest unit of a substance that has all the properties of that substance. For instance, a water molecule is the smallest unit that is still water. A water molecule can be divided into tiny parts called **atoms**. Each water molecule has two hydrogen atoms and one oxygen atom (thus water is written as H_2O). **Atoms** are the smallest building block of all matter. Molecules are made up of two or more atoms that bond together. **Matter** is made of atoms and is anything that takes up space (air, water, rocks and even people are examples of matter). Matter can exist in one of three main states: solid, liquid, and gas.

Materials are the physical substance of which a thing is made or can be made. Wood, plastics, glass, and metal are some examples of materials. The **properties** of polymers reflect what's going on at the ultra-tiny (molecular) level. So, polymers look, feel, and act differently depending on how their atoms and molecules are connected, as well as which molecules they're made up of! This makes polymers a very useful type of material - they can have many different **properties** and **functions**. Some polymers are stretchy like a rubber band, rubbery like a bouncy ball, tough like a football, hard and tough like a skateboard, soft like a sweater, silky and strong like a parachute, or even bulletproof.

There are **natural polymers** (which come from nature) and **synthetic polymers** (chemical compounds discovered by scientists and produced in a factory or laboratory). While plastics are one common example of polymers, there are many other materials which are also polymers. Examples of **natural polymers** include rubber (from the sap of rubber trees) and silk (from the cocoons of silkworms), starches in plants such as corn, and cellulose found in paper and trees. Polymers also include proteins (such as hair, nails, and tortoise shell). Scientists combine monomers into a variety of different polymer arrangements to make **synthetic polymers** that can be molded into solid objects or films. These materials are known as plastics. All plastics are polymers. Examples of plastics include polyvinyl chloride (PVC), polystyrene, and polyethylene. Although all plastics are polymers, not all polymers are plastics. Other examples of synthetic polymers are nylon, polyester, and silly putty. Because synthetic polymer chains are designed to specifically meet desired characteristics (strong, flexible, translucent, resistant to heat, etc.), the final polymer chain can be very strong and difficult to breakdown naturally (via UV rays, heat, bacteria, or water).

Two short videos from National Geographic provide helpful background for facilitators.
Plastic 101 found at: https://www.youtube.com/watch?v=ggh0Ptk3VGE&t=74s
A Brief History of How Plastic Has Changed Our World found at: https://www.youtube.com/watch?v=jQdBag_p6kE

"I Wonder Board"

While the professional science and engineering communities often require specialized training and tools, anyone can learn to engage in similar processes and practices! Activities encourage "wondering" and emphasize how important it is for adults to model and encourage curiosity in youth. These "wonders" are often turned into questions that can be investigated or studied. Consider posting an "I Wonder" board (see Front Matter for full explanation) to help surface these "wonders" and perhaps provide inspiration for your group to dig deeper into their curiosities.

Activity A

Cup Wars
(15-20 minutes)

Youth will test how heat affects different types of plastics, exploring how the properties of materials affect its function.

Facilitator Tip
Depending on the size of your group, you may want to set up three stations so youth can rotate in small groups, with one station for testing Sample A, one station for Sample B, and one for Sample C.

OPENING QUESTIONS AND PROMPTS

Use the following prompts to facilitate a group discussion to get youth thinking about what they know about the main learning objectives of the module. 1

- What are 3 different containers that you have used for a beverage in the last week? Explain why you chose that type of container.
- If you were having a party and you wanted to serve beverages, what types of containers might you choose?
- What would influence the type of container you'd choose?

Facilitator Tip
Refer back to the Scientist Story in Module 1 if your group has viewed the video or read the story. Chemists and Chemical Engineers rely on the composition of a material - its chemical structure and what it is made from - to design what a material looks like, how strong it is, what it feels like, and to have it perform specific functions.

1 SciGirls

Connect STEM experiences to lives

Explain the challenge: Your team is challenged to find out which plastic cups can hold a hot liquid (such as hot tea or hot cocoa).

To ensure safety in this activity, ask the group:

- What are some ways we could test these three cups to see how they withstand heat (like hot liquid)? (Youth will likely say we could pour hot water in them and watch what happens).
- Would there be any safety concerns with each type of test? (burn our hands, have hot water run all over)
- Emphasize that safety is a key consideration for any experiment. Scientists and engineers have to be sure that any experiment or test they try is safe. To keep us safe, we will be using a hair dryer for the heat source, instead of hot water.

PROCEDURE (EXPERIENCING)

1. Invite youth to examine each type of cup (Samples A, B & C), then answer the following questions, and make brief notes about the cups' appearance (size, texture, color, weight, and other observations) on the Cup Wars data sheet. Alternatively, you might want to have this conversation as a full group and record notes on flip chart paper.

2. Engage in group discussion, using these questions:
   - Based on appearance alone, what is the same and different with the three cups?
   - Do you think these are made of the same material? Why or why not?
   - Based on your observations, predict how each sample will hold up to the heat of the hair dryer.

3. Give a safety demonstration: Show youth how to hold their cups and blow dryer -- the youth can hold the cup right next to the blow dryer, but should keep their fingers out of the hot air. It can help to hold the cup upside down by the lip.

4. Invite each group to move to stations and to blow-dry their sample cups for 30 seconds. (Groups can repeat for another 30 seconds, observing at the end of each 30 second test. They may repeat for up to a total of 120 seconds or 4 sets of 30 seconds each). Guide youth to rotate to all three stations. Ask youth to make notes about their observations using the Cup Wars Data Sheet (Appendix A).

Facilitator Tip
Sample A "flows" within about 20 seconds. This means the plastic will warp and collapse. Sample B should be impacted only in a minor way (if at all). The results for Sample C will depend on the type of cup chosen; facilitators will have tested this sample prior to youth trying it so they will know how it reacts to heat.

5. Based on their observations, have youth draw conclusions about the ability of the cups to hold hot water based on how they reacted to the blow dryer test. Ask them to explain their conclusions.

Science and Engineering
Explain that scientists and engineers would do an experiment or redesign their plan more than once.

Facilitator Tip
Each group of three will spend about 30-120 seconds blow-drying each sample. What you should find is that Sample B is capable of holding a hot liquid, and Sample A is not. What about Sample C? (Because Sample C will vary based on the type of cup you have chosen, responses will vary also). For example, a Solo ™ brand cup will show some melting; testing a Dixie ™ brand, wax-covered paper cup may cause the wax to soften and become warm; other cups will vary so test before using.

SHARE/PROCESS/GENERALIZE:

Help guide youth as they question, share, and compare their observations. 2 You may choose one of the questions below as a prompt. If necessary, use more targeted questions as prompts to get to particular points. Remember these questions are not about getting one right answer. When the activity is completed, gather the whole group back together and lead a discussion with the following questions:

- Describe what happened with Sample A? Sample B? Sample C?
- What evidence did you gather through your observations that this cup would or would not hold hot liquid?
- Explain how these reactions are similar. Explain how they are different?
- What do you think causes the cups to react the way that they did?
- What do you notice about the plastic code on the cups we used?

Facilitator Tip
This may be a good time to discuss what materials plastics are made from: synthetic or "petroleum-based" are still our most common material to make plastics. PLA cups are plant-based plastics.

Science and Engineering
Articulate for youth that they have used another Science and Engineering Practice: 'Engaging in argument from evidence' and add it to the list. 2

- Clarify that the word argument in this context is defined as reasons given to support an idea and that in the investigation they just did, the cups are evidence that the plastics are made of different compositions of material.

"I Wonder Board"
Use this opportunity to wonder aloud and model the process of wondering and asking questions; use the I Wonder board. Some things you may wonder aloud about with your group include: I wonder if all of these can be recycled? I wonder if it costs more to buy the plastic that can hold both hot and cold liquids? I wonder if it would be better for the earth to use a different type of container instead of plastic cups? I wonder what other experiments we could try to give us more data?

2 SciGirls

Support as they investigate using STEM practices

Activity B

The Science Behind Cup Wars (15-20 minutes)

This activity helps demonstrate what is happening on a more molecular level and how different polymer structures result in different properties. Youth will first model a polymer chain by acting as "monomers," (single, repeating units, forming a chain) to form the polymer according to directions given by a facilitator. The facilitator will act as a chemist stringing the monomers into polymer chains. Youth will then draw from their experience from the plastic cup softening experiments and demonstrate what is happening to the polymer chains of a plastic cup (oil-based plastic) and a PLA cup (bio-based plastic) when heat is applied. Youth will learn about polymer chains and how they interact, and why plastics are functional as well as problematic for our earth.

OPENING QUESTIONS AND PROMPTS

Use the following prompts to facilitate a group discussion to get youth thinking about what they know about the main learning objectives of the module. 1

QUESTIONS BEFORE THE FIRST DEMONSTRATION OF A POLYMER CHAIN:

- Explain what you think might happen when you heat up a polymer.
- Explain how you think a scientist or chemist might change a polymer chain?

QUESTIONS BEFORE THE SECOND DEMONSTRATION OF POLYMER CHAIN WHEN HEAT IS APPLIED

- What do you think was happening to the PS plastic cup when it was softening/deforming?
- What do you think was happening to the PLA plastic cup when it was softeningdeforming?

1 SciGirls

Connect STEM experiences to lives

PROCEDURE (EXPERIENCING)

Use the following prompts to facilitate a group discussion to get youth thinking about what they know about the main learning objectives of the module.

1. First polymer demo: Explain that we are going to create a "human model" to explore the science behind what happened in Cup Wars. Ask for at least six volunteers who are willing to become a polymer chain. Ask them to stand in a line facing the rest of the group. Each of the youth will be a "monomer." Explain that the facilitator will be the chemist arranging the polymer chain by stringing the "monomers" together. The role of scientist is important because he/she is building the different polymers to achieve a desired material characteristic.

2. Ask the youth to grasp hands. Ask one youth on one end of the "Mer-Chain" to pull on the hand of the person next to him/her while the other five youth pull in the opposite direction. Discover what happens. If the "link" (holding of hands) breaks, challenge the youth to explore other ways their chain can move together (e.g. stand closer or further apart). The "chemist" can assist in adjusting the polymer chain. Trying pulling away again. Discover what happens. Prompt by asking: How else could you create a "mer chain" from (human) monomers? (accept ideas that connect the monomers, such as the youth could hold each other's hands, which would form a bond between each of these monomers; youth could link elbows to form another type of bond; youth could both hold onto a piece of yarn, string, rope or rubber band, which would also link them into a chain).

3. Second polymer demo simulating a PS plastic cup: Now ask nine (or more) youth to form three different mer-chains. One youth acting as the "chemist" works with the group to make three very flexible and easy to move mer-chains. The goal is for the mer-chains to be organized into three lines that are shoulder distance apart. The members within each mer-chain lock elbows to stay connected to each other. Ask one additional youth to act as the heat from the hairdryer. The "hairdryer" makes a loud noise representing heat and tries to move the links of each mer-chain further apart, but each mer-chain is hard to move together because they are so close to the others.

4. Third polymer demo simulating a PLA plastic Cup: Youth stand close to the others in their chain, linked by holding the end of a bandana. The "chemist" arranges each mer-chain into a new structure using the bandanas, representing a plant-based polymer, such as the PLA cup. The mer-chains are again ordered into neat lines. The "hairdryer" again makes a loud noise representing heat and as a result, the chain linkages spread apart and the bandana bonds move apart. The three mer-chains should take three large steps away from each other and can now move in multiple directions.

SHARE/PROCESS/GENERALIZE:

Help guide youth as they question, share, and compare their observations. **2** You may choose one of the questions below as a prompt. If necessary, use more targeted questions as prompts to get to particular points. Remember these questions are not about getting one right answer.

- Based on your experience from the activity,
  - Describe ways the hairdryer (heat) impacted the polymer chains of the plastic cup (cup B or C).
  - Describe ways the hairdryer (heat) impacted the polymer chains of the PLA plastic cup (cup A).
  - Explain how different bonds may have different flexibility. (Possible responses may include: the elbow linkage would be stronger than holding hands; holding hands would be stronger than joining index fingers. Possible explanations may include: the elbow bond puts people closer together; arm muscles are stronger than our hand muscles, certain linkages pull the chain closer together).
- Describe ways you were able to make the bonds more or less flexible. (Youth may describe ideas, such as having some people link to shoulders and others link by elbow, linking ankles by crossing their legs. Some of these may speak to how polymer chains can cross-link).

"I Wonder Board"
Challenge the group by modeling an "I Wonder" statement: Some materials need to function at high temperatures so how might we prevent the mer-chains from moving away from each other when heated?

Facilitator Tip
Using the human "mers" in your group, ask youth to demonstrate how they might cross-link with each other. Youth might link arms within their mer-chain and try to use a free hand to grab onto a different mer-chain, or they might use bandanas to tie chains together more tightly.

Science and Engineering
Articulate for youth that they have just used another practice of science and engineering: 'Developing and using models.' Add this to the poster or list which was started earlier. 2

- Summarize: We have discovered that polymers are long chains of molecules, which make them both very strong and durable. We learned that all plastics are made of polymers. Knowing this, share an example of how polymers could be helpful to us. Share an example of how polymers could be hurtful/harmful to us.

2 SciGirls
Support as they investigate using STEM practices

Activity C

Polymers: One Type of Material (10-15 minutes)

In this activity, youth explore polymers as one type of material, and discover that objects made of the same material can have different properties and functions.

OPENING QUESTIONS AND PROMPTS

Look around the room. Name some of the materials that objects in this room are made of.

Facilitator Tip
Materials are the physical substance of which something is made; these include wood, glass, polymers, metals, paper, cloth/textiles, and composites (combinations of various materials).

PROCEDURE (EXPERIENCING)

1. Gather youth around a table or circle on the floor on which you've placed 8-15 assorted objects made of polymers (rubber bands, bouncy ball, fleece jackets, tiny rubber Lego tires, a football, a CD case, Styrofoam (pool noodle or piece of packaging), plastic bags, plastic cup (re-usable, such as a child's cup), a PLA cup, plastic utensil, plastic beverage / coffee cup, etc.). (For a group larger than 10, you might create two or three tables of objects and divide the group between the tables).
2. Ask youth to individually examine each object for about 30 seconds, noting object strength, object flexibility, object purpose, and other similarities and differences between the objects.

Facilitator Tip
Encourage youth to touch, squeeze, or bend the items.

3. Ask youth to describe the properties of the objects and discuss what materials they think the objects are made of.

Facilitator Tip
Youth may describe the items as stretchy like the rubber band, rubbery like the bouncy ball or Lego tire, tough like a football, and stiff like a plastic cup. The material that all of these items are made of is polymers. All plastics are polymers. Even when objects are made of the same materials, they might look different and have different properties and functions.

4. Next, ask youth to work together to sort objects into two piles – what do you keep (use over and over) and what do you get rid of after using it (single use)?

SHARE/PROCESS/GENERALIZE

Help guide youth as they question, share, and compare their observations. 2 You may choose one of the questions below as a prompt. If necessary, use more targeted questions as prompts to get to particular points. Remember these questions are not about getting one right answer.

- Ask youth to share their observations about the objects and why they would keep or toss it.
- Discuss any disagreements youth had over how they sorted the objects. 3

Explain that this challenge, to decide what to do with objects once we are done with them, is one that we are faced with each day. When scientists and engineers think about sustainability, they need to consider what materials something should be made out of, how an item is made, and what happens to it once it is no longer needed. These criteria are important when we want to take care of our planet Earth.

2 SciGirls

Support as they investigate using STEM practices

3 SciGirls

Embrace struggle, overcome challenges, and increase self-confidence in STEM

Activity D

A Stop at the QuickShop Store (15-20 minutes)

Youth will learn about three materials and their properties: plastic, aluminum, and glass. Youth will consider the advantages and disadvantages of the material, and present an argument for what they understand to be the best option.

Facilitator Tip
Consider bringing in actual examples of food in packaging, such as metal cans or glass jars of food, different beverage containers, aluminum pouches, etc. to help youth visualize the wide variety of packaging materials.

OPENING QUESTIONS AND PROMPTS

- Describe different types of materials we use in our everyday lives to package food products. 1
- Explain why you think different materials are used.

PROCEDURE (EXPERIENCING)

1. Read aloud the following challenge to the youth:

   You are out for a walk and are really thirsty. You want something to drink, and your reusable water bottle is empty. The QuickShop convenience store is just down the street. Your favorite beverage comes in three different containers – glass, plastic and aluminum – and all contain the same amount. You also have your reusable water bottle. Which of the four would you choose for your drink?

2. Ask the youth to identify some of the criteria they would use to make their choice.

1 SciGirls
Connect STEM experiences to lives

Facilitator Tip
You may need to clarify that you are not asking them to state what is good or not-so-good about the containers, but rather that criteria is a standard by which something can be judged or evaluated, so as a group we are identifying how we might judge the four options. If needed, you may prompt the discussion by stating a criteria, such as cost.

3. Divide youth into four smaller groups, with no more than four youth per group. **5** If you need more than four small groups, two groups can have the same beverage container handout (i.e. two groups will have glass).
4. Give each group a paper (Appendix C) with one type of beverage container and facts about that product listed on it.
5. Challenge each group to read the facts listed and discuss the advantages and disadvantages of their container. Give them 4-5 minutes to discuss and decide how to present their facts and opinions to the full group.
6. Have youth present their information to the full group.
7. After the four groups present, youth will be asked to choose which container they believe is the wisest choice and be prepared to explain why.

(Use the flip chart paper to have each youth cast their vote. List each option and ask each youth to use a sticker to vote. You could also create a chart/graph of your votes).

Science and Engineering
One of the science and engineering practices is 'Using mathematical and computational thinking' which can now be added to the science and engineering practices list or noted on the poster.

5 SciGirls
STEM is collaborative, social, and community-oriented

SHARE/PROCESS/GENERALIZE

Help guide youth as they question, share, and compare their observations. 2 You may choose one of the questions below as a prompt. If necessary, use more targeted questions as prompts to get to particular points. Remember these questions are not about getting one right answer.

- Explain what you think were the most important criteria or properties for the container voted to be the "Best".
- Describe your reasoning behind your choice.
- Explain where you think the different containers would end up once they are empty. Describe any disagreements you had with your groups' list of advantages and disadvantages. 3
- Explain any challenges you faced when making a decision about the "best" container. 3
- Explain how this activity may influence your choices or your family's choices in the future. 1

Ensure Concept Understanding (10-15 minutes)

At this point, it is important to ensure that the terms **atom, function, matter, materials, monomer, natural polymer, polymer, properties, and synthetic polymer** have been discovered by or introduced to the youth. The goal is to have the youth discover terms and concepts on their own, defining them with their own words. After youth have stated and shared their understanding of the concepts, then you may introduce the terminology used by scientists to refer to the concepts. Facilitate a brief conversation on the importance of the concepts.

1 SciGirls

Connect STEM experiences to lives

2 SciGirls

Support as they investigate using STEM practices

3 SciGirls

Embrace struggle, overcome challenges, and increase self-confidence in STEM

SCIENCE & ENGINEERING IN EVERYDAY LIFE - CONCEPT APPLICATION

Facilitator Tip
When engaging youth in inquiry-based learning, hands-on activities serve as vehicles for learning new concept knowledge and skills; however, it is the application of new knowledge or skills to independent, real-world situations that is the critical factor in the learning process. Thus, to complete the cycle of experiential learning it is important to intentionally provide youth specific opportunities for authentic applications.

REFLECTION

Reflecting on experience is an essential part of learning and "making meaning of" an experience. Now is an opportunity to bring the youth together and discuss the things they experienced throughout the module. You may want to use a "circle share" process to facilitate this discussion. Have youth sit in a circle with you. Some general questions you can ask the youth include:

- Did you try something that you've never done before?
- What is something new you learned from the activities today?
- How were you a scientist or engineer today? 4
- Which of the eight practices of science and engineering did you use today? 2

2 SciGirls

Support as they investigate using STEM practices

4 SciGirls

Identify and challenge STEM stereotypes

EXTEND THE LEARNING

- **Science at Home** - These are possible extension activities that can be used with youth as time/interest allows. If you meet multiple times, you might invite youth to do a take home activity and have them report back or bring in an item as described. This helps support application of the concepts you've explored in this module. These activities are also shared on the Science at Home handout.

Facilitator Tip
Science at Home can be copied and sent home with the youth, or emailed. It includes a brief summary of the module and provides several activity ideas. It encourages families to engage in science learning together, supporting application of the concepts.

- **Service Learning in Action -** Planning and carrying out a service-learning project can be an exciting opportunity for youth to apply their learning as they work to address local and world needs. In Module 6: Service Learning, youth will dive deep into the experiential process by creating and carrying out a service project related to plastics. Below are some suggested activities and real-world service-learning examples that you can explore with your students related to plastics in our world.

- **Real-World Examples:**

  Isatou Ceesay in Njau, Gambia transforms discarded plastic bags into colorful purses. By turning plastic waste into useful products, Isatou also transformed her community. Check out her story at http://oneplasticbag.com/ or read the book One Plastic Bag.

  Liz Houck Kampa of St. Cloud, MN founded Weaving Love Inc., an organization that weaves plastic bags together to make rugs for the homeless. Check out her website at www.weavinglove.com

SERVICE IDEAS

- **Straw Reduction** - We all love straws, but what materials are they made of and how long is their lifecycle after we throw them away after just one use? Explore reusable alternatives to plastic straws. Tell a friend or others about what you've learned.

- **Ditch Plastic Shopping Bags** - Plastic shopping bags can pile up after just one use. They are not easily recycled and often end up in the ocean or landfills where they can be deadly to animals. Just like Liz Houck Kampa of St. Cloud MN, you too can weave rugs from plastic bags. Here are some instructions: https://www.persil.com/uk/dirt-is-good/arts-crafts/plastic-bag-weaving.html

SOURCES

Bottle Buyology. (2012, November 1). Minnesota Pollution Control Agency. Retrieved February 21, 2020, from https://www.pca.state.mn.us/featured/bottle-buyology

Dickrell, S. (2017). Groups weave mats for homeless people. St. Cloud Times. Retrieved February 21, 2020, from https://www.sctimes.com/story/news/local/homelesskids/2017/02/16/groups-weave-plastic-bags-into-mats-homeless-people/97720246/

National Geographic. (2018, May 18). *Plastics 101 | National Geographic* [Video]. Youtube. https://www.youtube.com/watch?v=ggh0Ptk3VGE&t=74s

National Geographic. (2018, May 22). *A Brief History of How Plastic Has Changed Our World | National Geographic* [Video]. Youtube. https://www.youtube.com/watch?v=jQdBag_p6kE

One Plastic Bag [Website]. (n.d.). Retrieved February 21, 2020, from http://oneplasticbag.com/

Parker, L. (2018). A whopping 91% of plastic isn't recycled. *National Geographic.* Retrieved February 21, 2020, from https://www.nationalgeographic.com/news/2017/07/plastic-produced-recycling-waste-ocean-trash-debris-environment/

Plastic Bag Weaving. (n.d.). Persil. Retrieved February 21, 2020, from https://www.persil.com/uk/dirt-is-good/arts-crafts/plastic-bag-weaving.html

Plastics Make it Possible [Website]. (n.d.). Retrieved February 21, 2020, from https://www.plasticsmakeitpossible.com/

Recycling. (n.d.). The Aluminum Association. Retrieved February 21, 2020, from https://www.aluminum.org/industries/production/recycling

The Facts: Glass. (n.d.). Recycling Coalition of Utah. Retrieved February 21, 2020, from https://utahrecycles.org/get-the-facts/the-facts-glass/

The Facts: Plastic. (n.d.). Recycling Coalition of Utah. Retrieved February 21, 2020, from https://utahrecycles.org/get-the-facts/the-facts-plastic/

Appendix A

Cup A: Sketch the Appearance BEFORE Heating:

(Include size, shape, texture, hardness, and color)

Make a Prediction:

Can this cup withstand heat? Yes or No.
Why do you think this?

Cup A: Sketch the Appearance AFTER 30 seconds of Heating:

(Include size, shape, texture, hardness, and color)

Make an Observation:

Did the cup withstand heat as you predicted? Why do you think it is or is not designed to withstand heat?

Appendix A
(Continued)

Cup B: Sketch the Appearance BEFORE Heating:

(Include size, shape, texture, hardness, and color)

Make a Prediction:
Can this cup withstand heat? Yes or No.
Why do you think this?

Cup B: Sketch the Appearance AFTER 30 seconds of Heating:

(Include size, shape, texture, hardness, and color)

Make an Observation:
Did the cup withstand heat as you predicted? Why do you think it is or is not designed to withstand heat?

Appendix A
(Continued)

Cup C: Sketch the Appearance BEFORE Heating:

(Include size, shape, texture, hardness, and color)

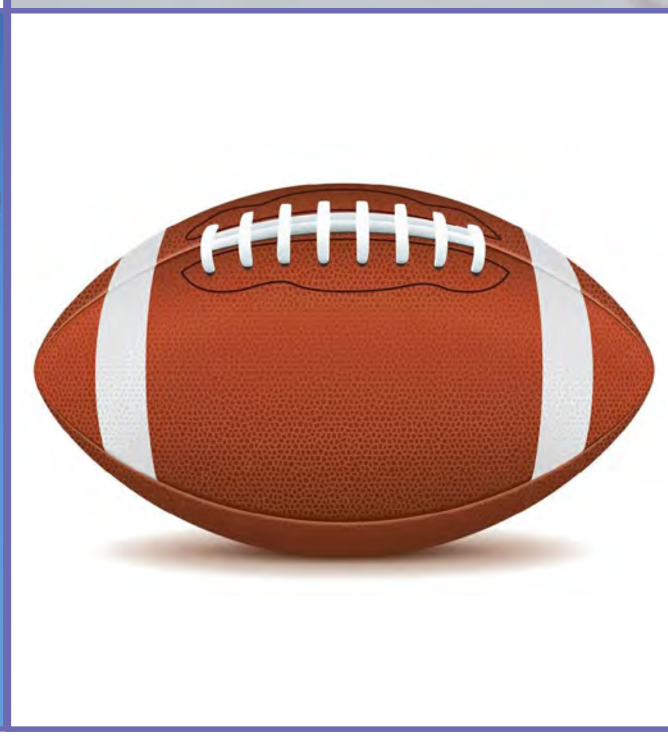
Make a Prediction:
Can this cup withstand heat? Yes or No.
Why do you think this?

Cup C: Sketch the Appearance AFTER 30 seconds of Heating:

(Include size, shape, texture, hardness, and color)

Make an Observation:
Did the cup withstand heat as you predicted? Why do you think it is or is not designed to withstand heat?

Appendix B



Appendix B
(Continued)

Rubber Band	Bouncy Ball
Football	Parachute

Appendix B
(Continued)



Appendix B
(Continued)

Skateboard	Bulletproof Vest
Plastic Silverware	Hair and Fingernails

Appendix B
(Continued)




Appendix B

(Continued)

Turtle Shell	Tree
DNA	Silly Putty

Appendix B
(Continued)

Appendix B
(Continued)

Rubber Car Tire

Appendix C

Container Description Sheet

Aluminum Can

Facts:

- Aluminum is a sustainable metal and is 100% recyclable.
- Nearly 75% of aluminum ever produced is still in use today.
- Energy saved from recycling one ton of aluminum is equivalent to the amount of electricity an average home uses over 10 years.
- There is no limit to the number of times aluminum cans can be recycled.

Brainstorm:

Pros to using aluminum cans:

Cons to using aluminum cans:

Appendix C
(Continued)

Container Description Sheet

Plastic Water Bottle

Facts:

- Plastic takes up to 1,000 years to degrade in a landfill.
- Only about 25% of the plastic produced in the U.S. is recycled.
- Recycling plastic takes 88% less energy than making plastic from raw materials.
- Americans throw away 35 billion plastic bottles every year.

Brainstorm:
Pros to using plastic water bottle:

Cons to using plastic water bottle:

Appendix C
(Continued)

Container Description Sheet

Glass Beverage Bottle

Facts:

- Glass bottles and jars are 100% recyclable and can be recycled endlessly without any loss in purity or quality.
- Glass takes 1,000,000 years to fully degrade in a landfill.
- Recycling glass takes 30% of the energy required to produce glass from raw materials.
- Recycling one glass bottle saves enough energy to light a 100-watt lightbulb for four hours.

Brainstorm:
Pros to using glass beverage bottle:

Cons to using glass beverage bottle:

Appendix C
(Continued)

Container Description Sheet

Reusable Water Bottle

Facts:

- Many different choices for reusable water bottles – glass, plastic, and stainless steel.
- Many types are still recyclable after the product life.
- Using tap water costs less. Water in the US is required to meet Federal water standards.

Brainstorm:
Pros to using a reusable plastic water bottle:

Cons to using a reusable plastic water bottle:

Science at Home

Hello Families,

Your child is exploring science and engineering in **Sustainable Polymers: Plastics of the Future for a Green, Clean World.**

In this week's lesson, **Materials Matter**, we explored how long chains of molecules that make up polymers and plastics affect the function of an object. We conducted a test to see how heat affects the different types of plastics.

We hope you try one or more of these "Science at Home" activities with your child. You and your child can have fun making discoveries together while practicing science and engineering skills.

Try these "Science at Home" Activities:

- **Share Your Polymer Learning:** Show your family members the different polymers that are around your home – natural polymers like fingernails and jello and synthetic polymers like plastic bottles and carpet.
- **Cup Wars at Home:** Try the Cup Wars experiment at home. Find different types of cups and create a data sheet as you test each one.
- **Cup War Video:** Create a video demonstrating the cup wars experiment and share your observations. Share how each cup is designed of specific materials to meet a desired need.
- **Research Plastics:** Research how plastics are made and what the typical life cycle is of plastics.
- **Plastic Benefits/ Plastic Challenges:** Work with your family to develop a list of plastics you use each day. Describe the benefits of the plastic items and the challenges of the plastic items.
- **Conduct an Experiment:** Compare how quickly organic waste decomposes when wrapped in plastic verses organic waste placed in soil. Observe if the plastic degrades over a set period of time. - https://www.science-sparks.com/easy-decomposition-experiment/

National Science Foundation

NSF Center for Sustainable Polymers

The SciGirls Strategies

Proven Strategies for Engaging Girls in STEM

The **SciGirls** approach is rooted in research about how to engage girls in STEM. A quarter of a century of studies have converged on a set of common strategies that work, and they have become the framework for **SciGirls**. The original set of strategies, created in 2010, were updated in 2019 to reflect current research.

1 Connect STEM experiences to girls' lives.

(Boucheretal.,2017;Sammetetal.,2016;Bonner&Dornerich,2016;Ereteetal.,2016;Stewart-Gardineretal.,2013;Civil,2016;Verdinetal.,2016;Cervantes-Soon,2016).

Make STEM real and meaningful by engaging girls in activities that draw on their interests, knowledge, skills, culture, and lived experiences. This helps girls develop a STEM identity and increases their sense of belonging in STEM.

2 Support girls as they investigate questions and solve problems using STEM practices.

(Buckholz et al., 2014; Kim, 2016; Scott & White, 2013; Farland-Smith, 2016; Munley & Rossiter, 2013; Civil, 2016; Riedinger et al., 2016)

Engage girls in hands-on, inquiry-based STEM experiences that incorporate practices used by STEM professionals. Let girls take ownership of their own STEM learning and engage in meaningful STEM work to positively impact their identities and re-define how they see STEM.

3 Empower girls to embrace struggle, overcome challenges, and increase self-confidence in STEM.

(Blackwell et al., 2007; Dweck, 2000; Halpern et al., 2007; Kim et al., 2007; Mueller & Dweck, 1998)

Help girls focus on and value the process of learning by supporting their strategies for problem solving and letting them know their skills can improve through practice. Support girls to develop a growth mindset—the belief that intelligence can develop with effort and learning.

4 Encourage girls to identify and challenge STEM stereotypes.

(Allenetal.,2017;Carlietal.,2016;Cheryanetal,2015;Robnett,2016;Allenetal.,2017;Carloneetal.,2015;Sammetetal.,2016,Scottetal.,2014;Tanetal.,2013;Dasguptaetal.,2014;Verdin et al., 2016; Civil, 2016; Boucher et al., 2017)

Support girls in pushing against existing stereotypes and the need to conform to gender roles. Helping girls make connections between their unique cultural and social backgrounds and STEM disciplines will negate potential stereotype barriers.

5 Emphasize that STEM is collaborative, social, and community-oriented.

(Capobiancoetal.,2015;Diekmanetal.,2015;Leaper,2015;Riedingeretal.,2016;Robnett,2013;Parker&Rennie,2002;Scantlebury&Baker,2007;Werner&Denner,2009;Cakiretal.,2017; Sammet et al., 2016; Boucher et al., 2017; Clark et al., 2016; Leaper, 2015)

Highlight the social nature of STEM to increase interest and motivation and change the stereotypical perception that STEM jobs require people to work alone. Girls benefit from a supportive environment that offers opportunities to build relationships and form a collective identity.

6 Provide opportunities for girls to interact with and learn from diverse STEM role models.

(Kochetal.,2015;Leaper,2015;Adamsetal.,2014;Jethwanietal.,2017;Kessels,2014;O'Brienetal.,2016;Levineetal.,2015;Hughesetal.,2013;Cheryanetal.,2015;Weisgram&Diekman,2017)

Introduce girls to diverse women role models from varied STEM career pathways to help girls see potential futures and develop resilient STEM identities. Positive role models can increase girls' interests in, positive attitudes toward, and identification with STEM.

Send us your Feedback!

Have you tried one (or more!) of the activities? Let us know how it went! We work with the Center for Applied Research and Education Improvement at the University of Minnesota to evaluate this project. Click on the button below to fill out their short evaluation form and help us collect valuable feedback for improvement!

4hpolymers.org/evaluation