NATIONAL
PEER REVIEWED

GRADES
6-8

Sustainable Polymers

Taking Action to Solve the Challenge of Plastics

A 4-H STEM Curriculum for Grades 6-8

National Science Foundation

NSF Center for Sustainable Polymers

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FRONT MATTER

GRADES 6-8

Sustainable Polymers

Taking Action to Solve the Challenge of Plastics

A 4-H STEM Curriculum for Grades 6-8

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4-H Polymer Science Curriculum for

Grades 6-8

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 note where the science and engineering practices are used. 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.

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Tips and Callouts

Facilitator Tips

These tips provide strategies and helpful suggestions for facilitators.

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.

Front Matter

Sustainable Polymers: Taking Action to Solve the Challenge of Plastics is a youth-driven curriculum focusing on the use and impacts of plastics and sustainability. The curriculum is designed to build foundational skills of science and engineering: observation, asking questions and defining problems, planning and carrying out investigations, and communicating. The curriculum contains three learning phases/modules intended for delivery in out-of-school time facilitated by an educator (trained volunteers or program staff). In each phase, youth will explore polymer science content through a guided activity and then become change agents through youth-driven projects.

CURRICULUM TARGET AUDIENCE

Youth in grades 6-8 (11 to 14 year olds)

DEVELOPED BY

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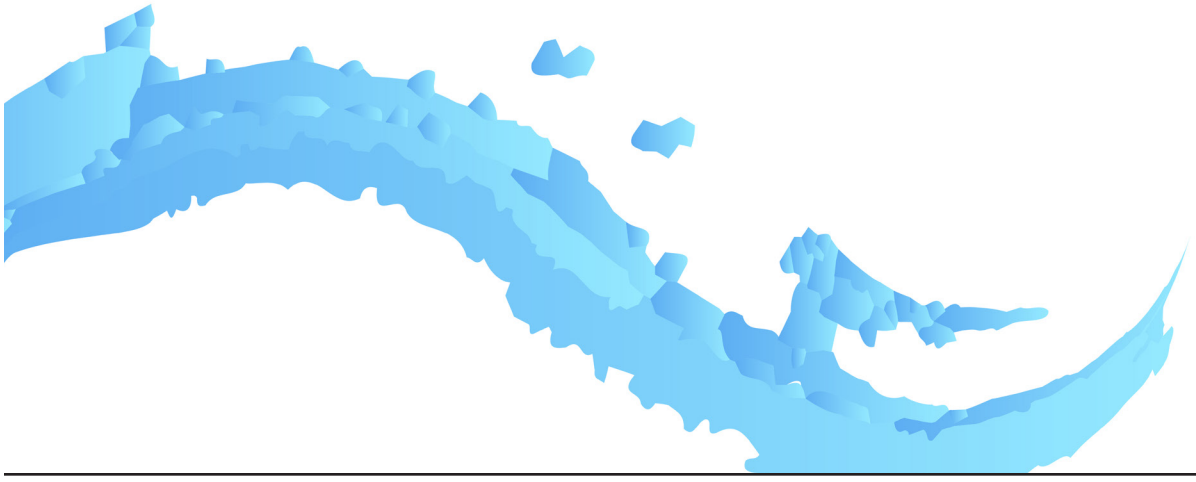

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INDIVIDUAL MODULE CITATIONS

- McCambridge, J., & Worker, S. (2020). Front Matter. In J. McCambridge, A. Mondl, A. Stevenson, & S. Worker (Eds.). *Sustainable polymers: Taking action to solve the challenge of plastics. A 4-H STEM curriculum for Grades 6-8.* NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- Worker, S., Panero, A., Cappa, A. Meehan, C., & Smith, M. (2020). The Plastic Past: Rise of the World's Most Popular Material. In J. McCambridge, A. Mondl, A. Stevenson, & S. Worker (Eds.). *Sustainable polymers: Taking action to solve the challenge of plastics. A 4-H STEM curriculum for Grades 6-8.* NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- Maille, A., & Malone, C. (2020). The Plastic Present: Inescapable Impacts of Polymers. In J. McCambridge, A. Mondl, A. Stevenson, & S. Worker (Eds.). *Sustainable polymers: Taking action to solve the challenge of plastics. A 4-H STEM curriculum for Grades 6-8.* NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- Mondl, A., Stevenson, A., & McCambridge, J. (2020). The Plastic Future: Search for Alternatives and Renewables.In J. McCambridge, A. Mondl, A. Stevenson, & S. Worker (Eds.). *Sustainable polymers: Taking action to solve the challenge of plastics. A 4-H STEM curriculum for Grades 6-8.* NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/

LEARNING OBJECTIVES SUMMARY

In this set of three modules, youth will explore concepts in sustainability and take positive action as change agents around a plastic issue impacting their communities. Youth will learn about the different types and uses of plastics, and explore the many benefits and challenges plastic can have on humans, animals, and the environment. Youth will gain polymer science content knowledge to understand how complex systems interact. They will discover and practice the skills used by scientists and engineers to learn about materials and their properties. Through their learning, youth will make informed decisions and work as change agents who actively contribute to the sustained health of their communities and environment.

MODULE SUMMARIES

1. The Plastic Past: Rise of the World's Most Popular Material
   Youth will prepare a marketing pitch to a beverage company for a container made from different types of materials using scientific information and life cycle analysis.

2. The Plastic Present: Inescapable Impacts of Polymers
   Youth will determine how disposal choices of plastics impact the environment through a human-sized board game.

3. The Plastic Future: Search for Alternatives and Renewables
   Youth will discover strategies to sustain the creation of plastics when the supply of materials is variable through a simulation game. Youth will also create polymer water pods to explore future uses for polymers.

CONTENT SUMMARY — THE IMPACTS OF PLASTIC

The theme of these modules focuses 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. Plastics can be strong and rigid (such as safety helmets and the exterior of automobiles) or soft and flexible (such as those used in shoe cushioning or plastics bags). It's easy to find examples of plastics in everyday life and we all encounter plastic items at multiple points each day. There are many advantages of using plastic as they can be lightweight alternatives that can save on fuel and energy.

Along with the many advantages of using plastics, there are disadvantages to their many uses. Plastics that end up littered in the environment can take hundreds or thousands of years to degrade. It is estimated that 4.8 million metric tons of plastics end up in our oceans each year. One of the best ways to dispose of plastics is through a recycling program. Plastics that are recycled can be reprocessed into the same item or converted into a different item. However, not all plastic makes its way to the recycling bin. Only about 8% of all plastic is recycled - the rest is either incinerated, put into a landfill, or ends up as pollution in the environment.

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. Some plastics are now designed to biodegrade without polluting the environment and others are created using renewable resources to lessen the dependence on traditional, oil-based plastics. Sustainable polymers must address the needs of consumers without damaging our environment, health, or economy.

LIFE SKILLS AND POSITIVE YOUTH DEVELOPMENT

Positive youth development builds on young people's strengths and assets. Youth development involves an intentional process that promotes positive outcomes for young people by providing opportunities, choices, caring relationships, and the support necessary for youth to fully participate in families and communities. High-quality programming provides valuable benefits in knowledge, skills, and interests, and also in the form of leadership development, life skills development, and civic development. Through participation in science and engineering education, youth should have opportunities to strengthen their competence, confidence, connection, character, caring/empathy, and contribute to their community.

Practices to support positive youth development:

- Establish a safe environment and build relationships. All youth need a caring, supportive relationship in their lives. Educators provide this by showing interest in, actively listening to, and fostering the assets of youth.
- Provide youth leadership opportunities. Creating opportunities for youth to develop skills and confidence for leadership and self-discipline is important for youth development.
- Provide community involvement experiences. Service forges bonds between youth and the community, and doing something valued by others raises feelings of self-worth and competence.

EXPERIENTIAL LEARNING CYCLE AND PROMOTING INQUIRY

The curriculum is designed around the teaching methods of inquiry and experiential learning. Experiential learning is a cyclical process where learners have opportunities to construct meaning through engaging experiences. The cycle includes multiple phases incorporating a concrete hands-on experience; a reflection phase where youth share, process, and generalize from the experience; and application of learning in new and authentic situations to deepen their understanding.

In a learning environment that promotes guided inquiry-based learning, youth build understanding through active exploration and questioning. The key to inquiry is that youth seek answers to questions rather than being given answers. This requires those who lead activities to facilitate the learning process and not simply disseminate knowledge. When activities are being led in an inquiry manner, youth actively question, observe, and manipulate objects in the environment.

EXPERIENTIAL LEARNING MODEL

Cooperative State Research, Education, and Extension Service (1996). Curriculum Development for Issues Programming - A Handbook for Extension Youth Development Professionals. Based on the work of Kolb, D. (1984). Experiential learning: Experience as the source of learning and development. New Jersey: Prentice-Hall.

EXPERIENTIAL LEARNING IN THE CURRICULUM

The curriculum outlines each activity around the experiential learning cycle:

- **Opening questions and prompts**: Before providing the materials for the experience, facilitate a group discussion to get youth thinking about what they know about the main learning objectives of the module.
- **Experiencing**: Provide procedures and instructions for a hands-on activity.
- **Sharing, Processing, Generalizing**: Help guide youth as they question, share, and compare their observations. Sample broad and open questions are included. Often, some of the sharing and processing takes place during "experiencing", however, it is vitally important to schedule time for group reflection after the activity. If necessary, use more targeted questions as prompts to get to particular learning points.
- **Concept and Term Discovery**: During this phase, it is important you ensure the primary learning objectives and concepts have been introduced or discovered by the youth. Important factors to include in term discovery are: (a) concepts must be stated in the young people's own words; (b) you may then introduce the terminology used by scientists to refer to the concepts; and (c) you should lead a brief conversation on the importance of the concepts.
- **Application**: The true test of learners' understanding is when they can apply new knowledge and skills to authentic situations. 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 where they will use what they learned. In this curriculum, the "Youth as Change Agents" serves an application for the polymer exploration activities.

RECOMMENDED EDUCATOR PRACTICES

The educator is a facilitator of learning, responsible for helping youth make meaning of their experiences. Educators are not expected to be the "sage on the stage" but rather the "guide on the side." Facilitating an open discussion is crucial in helping learners make meaning of their experience. Questions allow us to access information, analyze data, and draw sound conclusions. Good questions help stimulate thinking and creativity. To this end, broad and open questions are ideal in promoting discussion and interaction. They do not have a single right answer. In contrast, focused, narrow, and close-ended questions tend to be fact-based or solicit yes or no answers and do not promote discussion. Encouraging science talk has four purposes (elicitation, consolidation, data, and explanation) and may involve full group, small group, or partner discussions. For more about encouraging productive science talk, see Sarah Michael and Cathy O'Connor's Talk Science, Primer, at: https://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf

The curriculum emphasizes the use of embedded evaluation and formative strategies to assess learning which may occur in multiple places during the implementation of an activity. First, educators may assess youth understanding of the main concepts and their engagement with Next Generation Science Standards (NGSS) practices and concepts through the types of questions youth ask, moments of wonder or puzzlement, and being able to successfully complete the task. Second, when youth share their ideas and experiences, the educators can assess how well youth understood the primary learning objective through the activity. Additionally, during the sharing, processing, and generalizing phase, educators can ask more focused questions to assess youth understanding, particularly in the concept and term discovery. Finally, the application phase provides another opportunity to assess youth learning. Educators may have youth share their application activity at subsequent sessions.

CONNECTION TO THE "*SciGirls* Strategies"

These modules were designed to incorporate the SciGirls strategies for gender-equitable STEM learning. *SciGirls* is an Emmy award-winning PBS Kids television show, website, and educational outreach program that engages girls in science, technology, engineering, and math (STEM) learning. Using research, *SciGirls* outlines best practices in their "*SciGirls* Strategies." These strategies are used to target and engage girls in STEM learning but have also been proven to work with all learners, including underrepresented youth. In the individual modules, practices that correspond to one of the "*SciGirls* Strategies" will be identified.

The *SciGirls* strategies for gender-equitable STEM learning are:

1. Connect STEM experiences to lives of young people
2. Support youth as they investigate using STEM practices
3. Embrace struggle, overcome challenges, and increase self-confidence in STEM
4. Identify and challenge STEM stereotypes
5. Emphasize that STEM is collaborative, social, and community-oriented
6. Interact with and learn from diverse STEM role models

CONNECTIONS TO NEXT GENERATION SCIENCE STANDARDS (NGSS)

This collection of activity modules incorporate many of the science and engineering practices identified in the Next Generation Science Standards. Youth in grades 6-8 will work on their skills in these practices.

Science and Engineering Practices:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematical and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Youth explore many different disciplinary core ideas defined by NGSS through these modules. These core ideas span the physical sciences (PS), life sciences (LS), earth and space sciences (ESS), and engineering, technology, and the applications of science (ETS).

Disciplinary Core Ideas:

1. Chemical Reactions (PS1.B)
    - Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
2. Biodiversity and Humans (LS4.D)
    - Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.
3. Natural Resources (ESS3.A)
    - Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, freshwater, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

4. Human Impacts on Earth Systems (ESS3.C)

    - Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

    - Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

5. Defining and Delimiting Engineering Problems (ETS1.A)

    - The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

6. Developing Possible Solutions (ETS1.B)

    - A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.

    - There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

    - Models of all kinds are important for testing solutions.

7. Optimizing the Design Solution (ETS1.C)

    - Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.

    - The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

These modules also feature a number of crosscutting concepts. These concepts connect differing areas of content by providing related connections and tools.

Crosscutting Concepts:

1. Patterns

    - Graphs, charts, and images can be used to identify patterns in data.

2. Structure and Function

    - Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

- Cause and effect relationships are routinely identified, tested, and used to explain change.

3. Interdependence of Science, Engineering, and Technology

    - Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

4. Influence of Engineering, Technology, and Science, on Society and the Natural World

    - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

    - The uses of technologies and any limitation on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

5. Science Addresses Questions About the Natural and Material World

    - Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Together, the practices, core ideas, and crosscutting concepts covered through these modules mirror a number of performance expectations for youth in grades 6-8, such as:

- Gather and make sense of information to describe that synthetic materials come from natural resources and impact society (MS-PS1-3).

- Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment (MS-ESS3-3).

- Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems (MS-ESS-4).

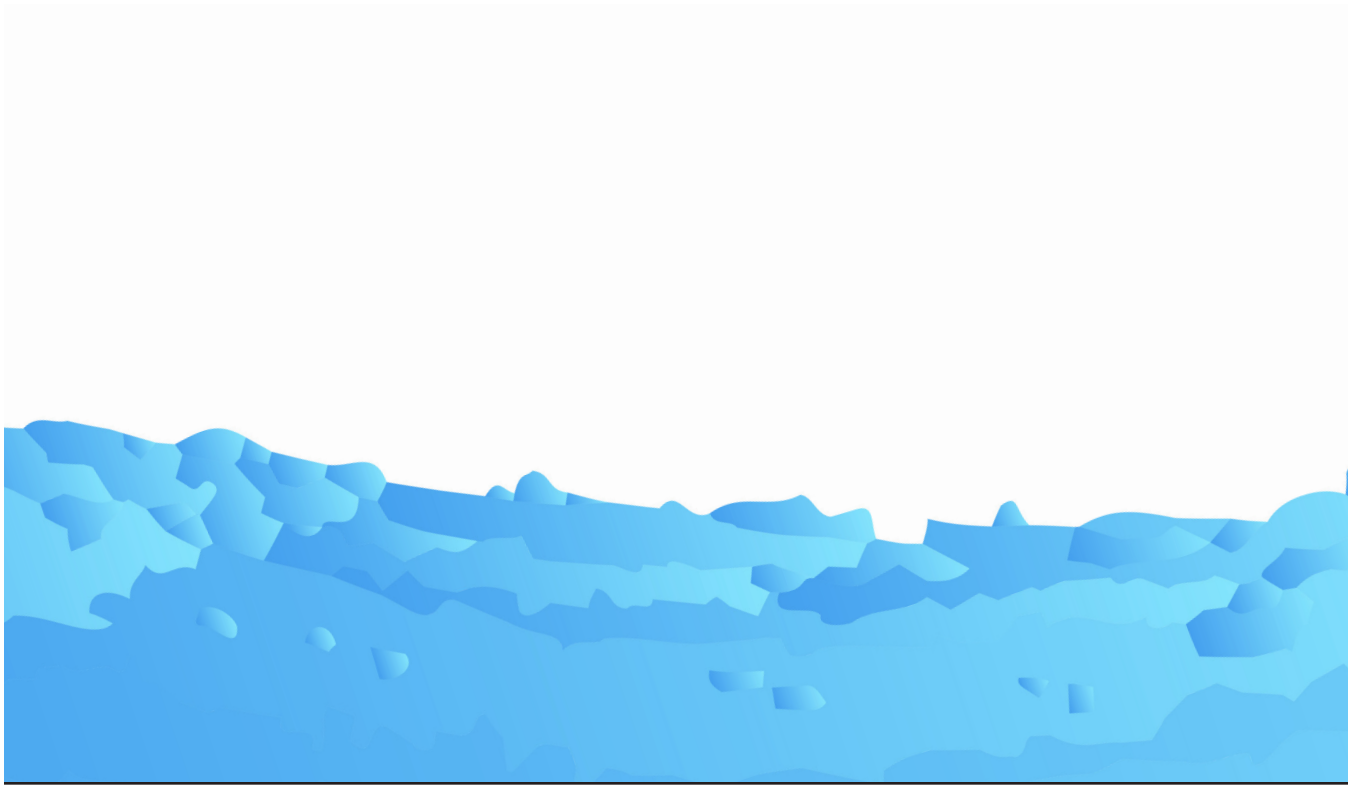
Facilitator Tools

Tips for Facilitating Group Discussions

Facilitators play an important role in guiding youth through the process of discussion and setting goals collaboratively. Begin creating a safe and supportive environment by using these group facilitation strategies:

1. Welcome youth.
2. Begin with an opening activity/energizer/icebreaker that helps create connection, a sense of belonging, and teamwork with youth in preparation for group discussion.
3. Create shared agreements with youth to collaboratively build an environment that supports open discussions and shared decision making. Here are some potential agreements that support a positive discussion:
    - Respect
    - Open communication - active listening, open sharing
    - Everyone has the opportunity to contribute ideas and take a leadership role with responsibilities.
    - Adults and youth share decisions making
    - Shared Investment - each member plays an important role in planning and working toward the desired outcomes. This leads to a sense of shared ownership and belonging.
4. Cultivate Youth Voice
    - Encourage youth to come up with ideas and share their perspective.
    - Encourage other points of view - no idea is a bad idea, ask for clarification.
    - Intentionally include quieter voices to offer opinions and participate.
5. Lead discussion using a variety of active discussion methods to engage youth (examples are included in the Examples of Active Discussion Methods section).

6. Support Collaboration (group mission; individual accountability)
    - Each participant is an important contributor to the project.
    - Help youth understand partnership and shared responsibility.
    - As a result, each participant should be sure to fulfill their commitment to the project and the group.
7. Manage Conflict
    - Lively debate may turn into disagreements. Help youth understand different points of view. Suggest phrases that youth can use to acknowledge the other point of view, even if they disagree with the statement. Phrases can include: "It's okay that we have different opinions on this," "Let's give each person a chance to share their opinion," or "Let's listen to understand what they are saying, not just to respond."
    - With younger youth, an objective method of decision making can be the best choice, such as the toss of a coin or "rock, paper, scissors."
8. Provide positive and concrete feedback
    - Acknowledge the assets, contributions, and commitment that youth dedicate to the project as well as their unique leadership skills
    - Offer specific feedback unique to the young person that encourages a growth mindset. For example, "I have seen how hard you have worked and how your persistence has made an impact on the project."



DISCUSSION WARM-UP EXAMPLES

The following warm-ups can be used to help get youth moving and connected around plastic related issues:

- **Matter of Opinion** - Create a series of statements regarding plastics and ask youth to line up based on their opinion regarding the statement using strongly agree at one end and strongly disagree at the other end. For example, use the statement "I believe plastics can be both useful and good for the environment." After youth have moved to the spot on the line that best presents their opinion, ask a few youth to volunteer to share their opinion with the larger group. This can also be expanded to four corners of the room with each corner discussing the statement. Pictures of plastics can be used to begin the conversation.
- **Photo of Mine** - This activity is geared to start exploring the issue, especially if youth are shy and hesitant to talk. Offer a range of photos related to plastics. Ask youth to choose a photo that strikes them. Once they have a photo, ask them to find a partner with a different photo. The pair then discuss the image and image meaning. Provide time for group sharing.
- **Knee to Knee** - Create two lines, each with equal numbers of youth facing each other. Provide a question or statement related to plastics. For example, "Can all plastics be recycled?" Give one minute for the pair to discuss the topic. After one minute, call for the group to switch with one line moving one person over to right. Then pose a second plastic related question. Continue for as many rounds as best works for the group. Ask youth to share important elements or thoughts from the conversations.
- **Ball Toss** - Ask youth to make a large circle. Use a ball (larger than a tennis ball) and ask students to toss the ball and share one question or belief related to plastics. Make sure all participants get a chance to toss the ball and share.
- **I Wonder** - Provide youth with a half sheet of paper or an index card. Ask students to write one thing they wonder about plastics (our use, the impact on the environment, or sustainability). Ask the students to place their paper or index card in a central pile once they are finished recording the thing they wonder. Next, ask students to take a different paper or index card and read out loud to the group.
- **Rose and a Thorn** - Ask youth to find a partner and ask them to share one "rose" or positive thing about plastics and one "thorn" or negative thing about plastics. After one minute of sharing, ask a few students to volunteer to share some examples of a rose and thorn. Facilitators can also play music as youth move, then when the music stops, youth can find a different partner to share.

DISCUSSION METHOD EXAMPLES

The following examples of discussion methods can be used to ensure all voice are heard, youth are working as a team to generate ideas, and creating innovative solutions together:

- **Rapid Post-It Brainstorm** - Provide a range of small color Post-It pads to students. Give students two minutes to write any plastic issue they can think of or may want to solve. Ask that they don't write solutions yet, but to focus on quickly listing the issues. After two minutes, ask students to post their notes on a board in front of the group. After the notes are posted, ask one youth to read notes and help identify themes. Choose the top 2-3 themes and lead a second round of two-minute rapid brainstorming focusing on potential solutions. Ask youth to post potential solutions. Ask one youth to read all the solution Post-Its and help identify themes. Discuss as a large group the most common plastic related issue and most common plastic related solution.
- **Rotation Brainstorm** - Around a room, post a designated number of poster papers each with a different topic heading, a statement, or a question related to a plastic issue (our use, the impact on the environment, or sustainability). Ask youth to visit one poster paper to add at least one thought or suggestion. After a designated amount of time (2-3 minutes), the facilitator calls "switch" for the youth to rotate to a different poster. Be sure everyone has an opportunity to contribute to each poster. Youth can switch as a group or move to the next poster in a different group. After youth have finished, a youth or facilitator reads from the posters. Discuss themes and suggestions as a large group.
- **Think-Pair-Share** - Provide youth with an article, a video, or interesting plastic items to review or consider. Group youth into pairs to share insights and discuss. After three minutes, ask for volunteers to share important points from the discussion.
- **Small-Group Rotation** - Create a set of 3-4 different questions or statements related to plastics (our use, the impact on the environment, or sustainability) and list each question on a different poster paper. Station one poster paper at each table. Divide youth into 3-4 groups. Each group will have five minutes at a table to discuss a specific question. Ask one youth to record discussions. After five minutes, ask the youth to visit a different table to discuss. Have enough rotations so participants can visit each question or statement. After all the rotations are complete, ask someone from each table to share insights from the poster recordings.
- **Know and Want to Know** - Create two posters 1) What do we know about plastics and 2) What do we want to know about plastics. Post the paper and ask youth to visit each poster and record thoughts. After brainstorming, ask for a volunteer to read from the posters. As a group, identify themes.
- **Twenty Questions** - Ask youth to work with a partner to brainstorm 20 questions they have related to plastics (our use, the impact on the environment, or sustainability). Ask youth to share their list of questions. Identify the top five common questions to explore. As a large group, select the question the group is most interested in finding the answers.

Youth As Change Agents

CORE LEARNING EXPERIENCES

In each module, youth will have the opportunity to work as change agents in their local communities. Youth will design a project to address the driving questions related to plastics and sustainability. As youth explore and develop their projects, they will go through common learning experiences:

1. **Discovering the action project**
    - Ask questions and discuss issues related to plastics
    - Brainstorm/ generate ideas for a project/plan to address the issue
    - Record ideas
    - Identify what additional information is needed to select a project/plan
    - Determine ways to address/solve the issue
    - Identify how the project will make a positive change
    - Select a project
2. **Planning the action project**
    - Discuss and determine project goals
    - Identify resources
    - Create action steps/data collection plan to guide the project
    - Determine who will do what by when
3. **Putting the plan into action**
    - Implement action plan
    - Analyze the project's impact
    - Share project impact/project research
    - Determine project sustainability
4. **Sharing and reflecting on the action project**
    - Evaluate the project
    - Reflect on personal learning
    - Publicly showcase the project
    - Share results with community
    - Celebrate project impacts and personal contributions

CHANGE AGENT APPROACH MATRIX

There are several inquiry-based approaches that can be used when guiding youth through developing and implementing an action project around a plastic issue. The Change Agent Approach Matrix can help determine the approach that best fits the action question youth want to address. Examples are provided for each approach.

APPROACH DEFINITIONS	APPROACH PROCEDURES (FULL LEARNING CYCLE)	APPROACH EXAMPLES	SAMPLE QUESTIONS
Citizen/Community Science Youth work with scientists to collect data used to study real-world phenomena, or youth report data to a database or program which supports the work of professional scientists Program Model Example: for programs delivered at or near natural resources locations, such as park facilities, nature centers, and have direct connection with scientists and field experts	**Citizen/Community Science** Discover your research question • Identify experts or current research on your plastic issues • Determine how your project might fit with other plastic-focused projects • Create your data collection plan • Collect & analyze your data • Share findings • **Resources**: https://scistarter.org/ and https://www.citizenscience.gov/#	**Citizen/Community Science** Volunteers study ocean debris washed ashore and team up with a local university to study how the currents move debris through the water. https://www.frostscience.org/marine-debris/ Community members collect data on the microplastics in their coastal areas. https://microplasticsurvey.org/	**Citizen/Community Science** How much litter in or near our waterways are plastics? What is the most common type of plastic litter in our community? How much plastic is recycled in our community each month? What current plastic related research is happening in our community (at nature centers, education institutions, city/county government)? Who are the scientists working on plastic issues in our community or world?

APPROACH DEFINITIONS	APPROACH PROCEDURES (FULL LEARNING CYCLE)	APPROACH EXAMPLES	SAMPLE QUESTIONS
Geo-inquiry Youth analyze space, place, and human conditions through maps usually with the aid of geographic information systems (GIS). Program Model Example: for programs delivered at sites with access to GIS technologies, such as college campuses, scientific facilities, libraries, etc.	**Geo-inquiry** • Discover your question around plastics • Research your plastic topic • Identify resources (community experts, organizations) • Determine what and how you will collect data (survey, interview, observations, videos) • Analyze and map your data: how is the data connected; what visuals can show connections • Develop a geo-inquiry story: outline geo-inquiry • Create storyboard • Determine multimedia approach • **Resources**: https://www.nationalgeographic.org/education/programs/geo-inquiry/	**Geo-Inquiry Example** Students in Kansas City, Missouri learned about their local watershed. While collecting water quality samples the students noticed a large amount of plastic trash. This observation led the students to explore how they were impacting the local watershed with solid waste and what they could do about it. https://www.arcgis.com/apps/Cascade/index	**Geo-Inquiry** Where does the plastic pollution in our river come from and how can we educate our community about these problems? Where is plastic pollution coming from in our community? What might be an explanation for this plastic pollution? What places of business generate the most single-use plastics in our community? Where is plastic pollution impacting our watershed the most?

APPROACH DEFINITIONS	APPROACH PROCEDURES (FULL LEARNING CYCLE)	APPROACH EXAMPLES	SAMPLE QUESTIONS
Community Engagement Youth get involved in an organized effort on behalf of another government or nonprofit organization to benefit the community. Program Model Example: for programs delivered in partnership with a local neighborhood, community, or shared issue	**Community Engagement** Discover the plastic issue within your community • Research what is happening in your community • Interview community members, officials, etc. about the plastic issue • Collaborate with government and businesses • Identify project partners and community resources (e.g. school principal) • Create an action plan • Implement community action plan/advocacy plan • Analyze and publicly share impact • Resources: https://digitalcommons.unomaha.edu/cgi/viewcontent.	**Community Engagement** In response to the amount of waste New York City public schools were throwing away with styrofoam trays, the organization Cafeteria Culture worked to eliminate these foam trays from all NYC lunchrooms. Youth take on leadership roles as Cafeteria Rangers to assist with correct garbage sorting at their schools. http://www.cafeteriaculture.org/our-story.html Reduce School Lunch Waste resources from the US Environmental Protection Agency https://www.epa.gov/students/pack-waste-free-lunch	**Community Engagement** What concerns do youth and adults have about plastics in our community? How might we advocate for our community to stop using plastic straws and other one-use plastic items? What approach might be successful to change the way our school, community, and businesses discard plastic waste? What does our community need to know about plastic recycling?

APPROACH DEFINITIONS	APPROACH PROCEDURES (FULL LEARNING CYCLE)	APPROACH EXAMPLES	SAMPLE QUESTIONS
Service-learning Youth develop a project to benefit others and their community. Service-learning is a direct-service, indirect service, or advocacy-based service project that does not include data collection. Program Model Example: for programs delivered in partnership with a local neighborhood, community, or shared issue	**Service learning** • Discover the plastic issue you want to address • Research the plastic issue • Determine the best project to address the plastic issue • Plan the service action plan - who will do what, when, and where • Secure needed resources or partners (people, materials) • Implement service plan • Reflect on learning through focused activities (personal learning and how it is related to broader learning/experiences) • Identify and share project impacts and if applicable sustainability Resources:	**Service Learning** Youth from Indiana Public School # 91 created Zero Waste Free Cafeteria from a service learning grant they received to address school waste. They worked with Earth Charter Indiana to create a project that resulted in 75% reduction in school waste. Upcycle Plastics into Art - Combine your desire to make positive change with your artistic spirit by upcycling plastics into art!	**Service Learning** What should we do to teach others to reuse a plastic bottle instead of throwing it away? How can we create a school recycling program? Where do we see plastic litter in our neighborhood? What can we do to help clean it up and prevent future waste from collecting here? What challenges do local recyclers face with recycling plastics?

APPROACH DEFINITIONS	APPROACH PROCEDURES (FULL LEARNING CYCLE)	APPROACH EXAMPLES	SAMPLE QUESTIONS
Youth participatory action research (YPAR) Youth define an issue and research question, conduct an investigation (data collection, analysis), and then take action based on the results. In YPAR, youth develop a project where they collect and analyze data, followed by a service-learning project informed by their data outcomes. Program Model Example: for programs delivered with stakeholder observation and involvement	**Youth participatory action research (YPAR)** • Discover the plastic issue • Explore how the issue impacts you/your community • Develop your research question and data collection methods • Identify strengths, resources, and stakeholders • Collect and analyze data • Determine what change do you want to see • Identify who needs to know (local governments, businesses, schools, policymakers, etc.) • Create a plan to share the information, evaluate impact, determine sustainability • Resources: http://yparhub.berkeley.edu/	**Youth participatory action research (YPAR)** Youth design investigation to learn about how plastics in their community get into the watershed. Then they use what they learned to involve their community in reducing the amount of plastics that get into the watershed. Youth wondered what their classmates thought about recycling. So they posed a research question: How important do middle school students think it is to recycle plastic, aluminum, and glass? What helps or hinders them in recycling? They designed a survey with the help of their teacher, and collected 125 responses. They analyzed data and determined what their classmates thought. Students then embarked on an education and awareness campaign, and talked to their principal and custodian about reducing barriers to recycling.	**YPAR Sample** Authentic YPAR questions need to be created and driven by youth participants. Examples: How much plastic do we throw away each week in our classroom? What do people in our community remember about materials we used before plastics? How do our middle school classmates feel about recycling? What messages would work to convince our middle school classmates to switch to reusable beverage containers instead of one-use containers?

YOUTH AS CHANGE AGENTS-CORE LEARNING EXPERIENCES

As facilitators guide youth through the process of developing an action project, there are core learning experiences and guiding questions that are common across each inquiry-based approach. Facilitators will guide youth as they: 1) discover the action project, 2) plan the action project, 3) put the project into action, 4) share and reflect on the action project.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Discovering the Action Project • Youth ask questions and discuss issues related to plastics. • Youth brainstorm/ generate ideas for a project/plan to address the issue. • Youth record ideas. • Youth identify what additional information is needed to select a project/plan. • Youth determine ways to address/ solve the issue. • Youth will identify how the project will make a positive change. • Youth select a project.	**Discovering the Action Project** • What do we already know about plastics in our community/ in our world? • What do we wonder about plastic use and the environment? • What information do we need to know about plastics in our community or world (research)? • What critical issue related to plastic use and its environmental impacts do we want to address? • What action can we take to answer or address the question or issue? • How do the polymer science explorations influence how we want to take action?

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Planning the Action Project • Youth discuss and determine project goals. • Youth identify resources. • Youth create action steps/data collection plan to guide the project. • Youth determine who will do what by when.	**Planning the Action Project** • What do we want to achieve in this project? • What skills do we need to accomplish this project? How could we gain them? Who can help? • Who can we invite to partner with us on planning the project (elected officials/government representatives, businesses, schools or non-profits)? • What steps do we need to take to achieve this goal? • What resources do we need to help us achieve our goal? • What is our timeline - which activities will we do when? • What are the roles for our group members (who will do what by when)? • What else do we need to know to help us be more prepared for this project?
Putting the Plan into Action • Youth implement an action plan. • Youth share project impact/project research. • Youth determine project sustainability.	**Putting the Plan into Action** • What final preparation steps do we need to take in order to implement the plan? • Are there additional people we can invite as we put the plan into action - peers, family members, community members, leaders, others? • How will we record what we did? • How will we share the results of our work? Is it already part of the project (for example, in a Citizen/Community Science project protocol)?

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Sharing and Reflecting on the Action Project • Youth analyze and evaluate the project's impact. • Youth reflect on personal learning. • Youth publicly showcase the project. • Youth share results with community and stakeholders. • Youth celebrate project impact and personal contributions.	**Sharing and Reflecting on the Action Project** **Youth Learning:** • Why did we choose this project? • What did we accomplish? • What ways did we impact the plastic issue in our community/world? • Are there new questions or ideas? • If we were to do this project again, what would we do differently? • How might we or the community continue elements of the project? **Youth Leading:** • What did we learn? What skills did we gain? • What was our favorite part of the project? The hardest part? • How do we feel about what we accomplished in the project? • How do we feel about how our group worked together during the project? • What leadership skills did we gain through the project? **Celebrating:** • Who helped us along the way? How should we thank them? • Who else can help share our findings? How can they help us continue our efforts? • How can we all celebrate together?

Change Agent

1
PROJECT SELECTION TOOL

Here are some questions to consider:

- What is the most important plastic issue we want to help solve?
- How do we know this is a problem or issue? (What data do we have?)
- How can we share what we learned to help solve the problem?
- What do we want to learn during our action project?
- What do we want to accomplish in our action project?

PROJECT IDEAS

OUR PROJECT RECOMMENDATION IS...

WHY DO WE WANT TO DO THIS PROJECT?

Change Agent

2
PROJECT PLANNING TOOL

The Change Agent Project Planning Tool can be used when developing a detailed project plan to solve a plastic issue. The plan outline outlines the tasks that need to be done, who will do them, and when they will be accomplished.

- ✓ Identify specific tasks to be accomplished in order to address the plastic issue.
- ✓ Decide when, and in what order, each task needs to be done. Make sure that you give enough time for each task.
- ✓ Decide who will be the team leader for each task. Volunteer for specific duties and stick to your commitments.

PROJECT NAME	
PROJECT GOAL	
DATE(S) OF SERVICE	

WHAT ARE WE PLANNING TO DO? (ACTION STEPS)	WHO IS RESPONSIBLE?	DATE TO BE COMPLETED	FOLLOW-UP NEEDED

Change Agent

3
PROJECT EVALUATION

Action Project Title: _____Name_____

Explain how your project addressed an issue related to plastics.	**What difference do you think you made related to the challenge of plastics?**
Describe how you applied what you learned in the Polymer Science curriculum to your action project.	**If you were going to do this project again, what would you do differently? Explain how you collaborated with other groups, individuals, or organizations.**
Describe what you learned in the action project.	**How, in your opinion, could you adapt your project in the future to make it even more impactful?**

POLYMER SCIENCE EXPLORATION ACTIVITIES GRID

Find all activities at: 4hpolymers.org/polymerx

POLYMER SCIENCE ACTIVITY	ACTIVITY SUMMARY	THEME AND SUGGESTED CORRESPONDING MODULE
Cup Wars	In this activity, youth will explore different types of plastics, including petroleum-based and plant-based plastics. They will conduct a test to see how heat affects these different plastics.	**SCIENCE AND ENGINEERING IN SOCIETY** Module 3
Engineering Consultant Challenge	Youth become engineering consultants and work as a team to plan a group activity that promotes sustainable consumer decisions.	**SCIENCE AND ENGINEERING IN SOCIETY** Module 2
Polymer Scientist Change Agents	Youth will hear from polymer scientists at the NSF Center For Sustainable Polymers who are driven to address the environmental challenges that are inherently associated with traditional (petroleum-based) plastics.	**SCIENCE AND ENGINEERING IN SOCIETY** Module 3

POLYMER SCIENCE EXPLORATION ACTIVITIES GRID

Find all activities at: 4hpolymers.org/polymerx

POLYMER SCIENCE ACTIVITY	ACTIVITY SUMMARY	THEME AND SUGGESTED CORRESPONDING MODULE
Making Bioplastics	In this activity, youth will create their own bioplastic from cornstarch, vegetable oil, and water. Please note, a microwave is needed.	**SUSTAINABILITY** Module 3
Old Plastics into New Products	In this activity, youth fuse old plastic bags using an iron to create new products like bags, coasters, mats or rugs.	**SUSTAINABILITY** Module 3
Youth as Change Agents	Youth will learn about a wide range of young people and adults working to address the challenge of plastics. Suggested projects are also included.	**SUSTAINABILITY** Module 1
We're Going to a Beach Party	The goal of this activity is for youth to begin to explore the consequences of different material choices by deciding what kind of plates, forks, and eating utensils to bring to a party.	**IMPACTS OF PLASTICS** Module 2
Plastic Sculpture Challenge	The Plastic Sculpture Challenge includes 4 lessons to explore the world of plastics, including making an amazing piece of art by repurposing (upcycling) single use plastics, conducting a household plastic audit, learning about the Resin Identification Code (numbers) on plastic containers, and sharing learning. Groups can create a final showcase of the plastic sculptures created by youth.	**IMPACTS OF PLASTICS**
Lunch Time Waste Audit	Youth will conduct a lunch time waste audit to discover the most commonly discarded plastic lunch items. Then they will make recommendations on alternatives to the plastic lunch items.	**IMPACTS OF PLASTICS**

GRADE 6-8 GLOSSARY

- **Aluminum**: a silvery-white, lightweight non-magnetic metal.
- **Biodegradable**: capable of being decomposed by bacteria and other microorganisms
- **Bioplastic**: polymers often made from starch-containing plants, such as corn and potatoes. Many of these bioplastics are compostable.
- **Carbon footprint**: the amount of carbon dioxide produced due to the consumption of fossil fuels through human activities (e.g., transportation, electricity generation, agriculture, manufacturing).
- **Change agent**: youth leaders who transform their ideas into actionable projects to create positive social impact.
- **Disposal**: the action or process of throwing away or getting rid of something.
- **Glass**: a hard, brittle substance made from sand.
- **Industrial compost facility**: site where organic waste products go through a multi-step process converting items into usable soil.
- **Landfill**: site where waste from the community is taken.
- **Life cycle**: the extraction of raw materials; manufacturing of the product; the transportation of the product; the use of the product by the consumer; and the disposal or recovery of the product.
- **Life cycle assessment**: evaluates the environmental impacts of the extraction of raw materials; manufacturing of the product; the transportation of the product; the use of the product by the consumer; and the disposal or recovery of the product.
- **Litter**: items not disposed in recycling, compost, or trash receptacles are instead disposed of in the environment.
- **Microplastics**: tiny pieces of plastic.
- **Non-renewable resource**: resources that are only available in limited quantities and take a long time to be replenished (i.e. millions of years).
- **Petroleum**: oil extracted from the earth that can be used for fuel or made into plastic.
- **Plastic**: a type of material made from polymers that can be molded into solid objects. Usually made from petroleum/oil.
- **Pollution**: contamination by waste, chemicals, or other harmful substances to an environment.
- **Polylactic acid (PLA)**: a specific type of bioplastic derived from plant materials, usually corn.

- **Polymers**: chemical compounds formed from long repeating chains of smaller molecules.
- **Recycle**: process of converting waste materials into new objects.
- **Refuse**: decline to use an item and identify alternatives.
- **Renewable resource**: resources that can be replenished, often within one person's lifetime.
- **Repurpose**: use an object for a new purpose other than it was originally intended.
- **Reuse**: find a way to use again; or sell/donate for another to use.
- **Trend**: a way of demonstrating change over time.
- **Single-use**: an item that is thrown away after being used only once.
- **Sustainable**: able to be maintained or run continuously with little to no negative impact on the environment or health.
- **Sustainable polymer**: a plastic material that addresses the needs of consumers without damaging our environment, health, and economy.

NATIONAL
PEER REVIEWED

MODULE
1
GRADES 6-8

Sustainable Polymers

Taking Action to Solve the Challenge of Plastics

A 4-H STEM Curriculum for Grades 6-8

National Science Foundation

NSF Center for Sustainable Polymers

4-H Polymer Science Curriculum for

Grades 6-8

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 note where the science and engineering practices are used. 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

Facilitator Tips

These tips provide strategies and helpful suggestions for facilitators.

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 1

The Plastic Past: Rise of the World's Most Popular Material

Driving Questions:

- **Why have plastics become one of the most utilized materials in the world?**
- **What are some environmental impacts of plastics and alternative materials such as aluminum and glass?**

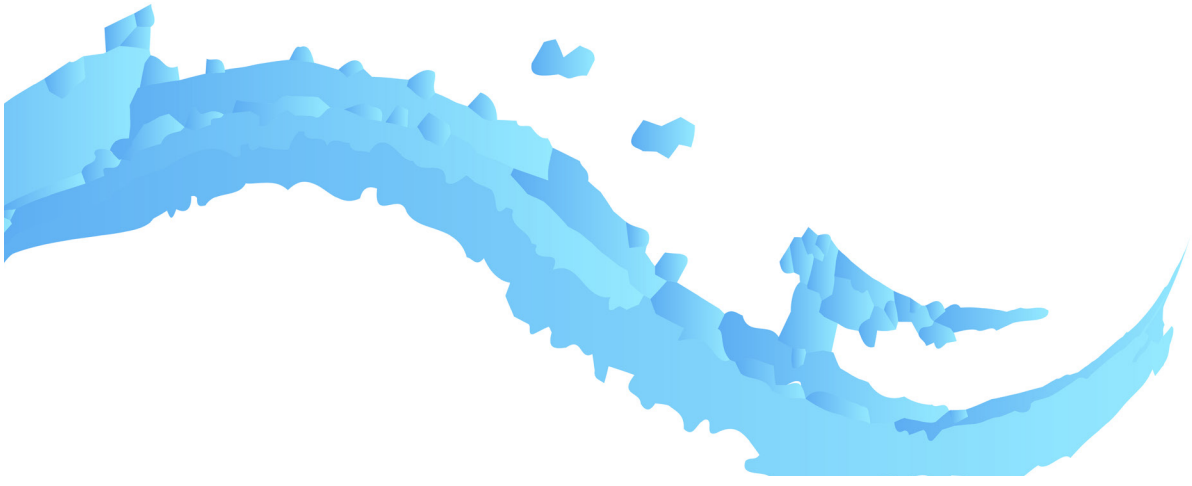
Introduction

MODULE SUMMARY

Youth will prepare and deliver a marketing pitch to a fictional beverage company for a beverage container made from their assigned type of material (plastic, aluminum, or glass) using scientific information. Afterward, youth will reflect as a large group on the advantages and disadvantages of each type of material. The questions they ask and explanations they develop will help guide them toward a youth-driven action project of their own design.

Time Required: 2+ meetings depending on youth-driven action project

- Set up for activity: 10 minutes
- Polymer Science Inquiry activity: Pitch Your Material (75-110 minutes)
- Youth as Change Agents activity: Youth-driven projects (varies, 60-120 minutes)



Module Focus

LEARNING OBJECTIVES	• Youth will explore the history of plastics, glass, and aluminum use. • Youth will interpret data as they pertain to the environmental impacts of different types of packaging and other plastic products. • Youth will describe strategies to mitigate the effects of packaging and other types of materials in their homes and communities.
SCIENCE & ENGINEERING PRACTICES (NGSS) 2	• Engaging in argument from evidence. • Analyzing and interpreting data. • Constructing explanations and designing solutions.
CONCEPTS & VOCABULARY	• **Aluminum**: a silvery-white, lightweight, non-magnetic metal. • **Carbon footprint**: the amount of carbon dioxide produced due to the consumption of fossil fuels through human activities (e.g., transportation, electricity generation, agriculture, manufacturing). • **Change agent**: youth leaders who transform their ideas into actionable projects to create positive social impact. • **Disposal**: the action or process of throwing away or getting rid of something.

2 SciGirls

Support as they investigate using STEM practices

Module Focus (Continued)

CONCEPTS & VOCABULARY

- **Glass**: a hard, brittle substance made from sand.
- **Landfill**: site where waste from the community is taken.
- **Life cycle**: the extraction of raw materials; manufacturing of the product; the transportation of the product; the use of the product by the consumer; and the disposal or recovery of the product.
- **Plastic**: a type of material made from polymers that can be molded into solid objects. Usually made from petroleum/oil.
- **Recycle**: process of converting waste materials into new objects.
- **Trend**: a way of demonstrating change over time.

Facilitator Preparation

MATERIALS NEEDED

- ☐ Copies of Appendix A-1 (blank life cycle handout); one per group.
- ☐ Copy a set of life cycle cards from Appendix A-2 ; one set per group.
- ☐ Copies of Appendix B (historical graphs of plastic, aluminum, and glass usage and recycling); one for each group.
- ☐ Copies of Appendices C-1, C-2, and C-3 (material information sheets for plastic, aluminum, and glass); one per group.
- ☐ Flip chart paper and markers

GETTING READY

- Cut out life cycle cards from Appendix A-2.
- Print copies of handouts for each pair/small group.

YOUTH AS CHANGE AGENTS

- ☐ Flip chart paper
- ☐ Markers
- ☐ Copy of Change Agent Approach Matrix - see Front Matter Facilitation Tools

YOUTH AS CHANGE AGENTS

- Review Change Agent Approach Matrix in Front Matter Facilitation Tools
- For tips on supporting open discussion and collective decision making, see Front Matter Facilitation Tools for active group facilitation strategies.

Background Information for the Facilitator

For thousands of years, people have used various containers to store beverages. The types of materials used to make these containers have varied depending on the availability of **raw materials** and cultural traditions. Over time, new types of materials have been developed and often replaced previous ones. For example, glass containers were replaced by aluminum containers. The production of glass from sand, and the weight of glass to transport, created a large **carbon footprint**; aluminum was much lighter and easier to transport.

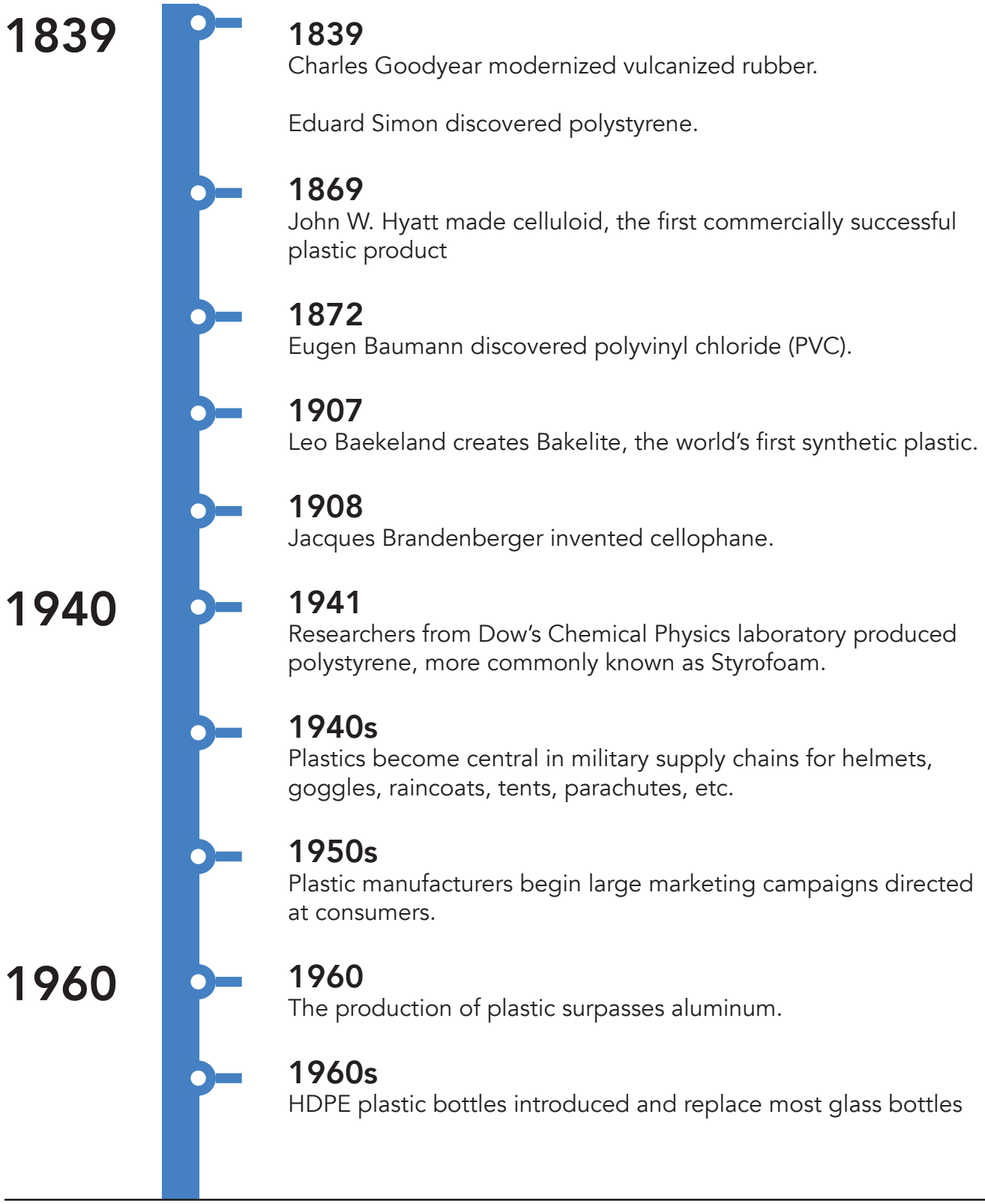
The history of plastics began over 3,500 years ago. One of the first documented uses of natural plastic comes from a Pre-Columbian civilization's ceremonial ballgame, which used a ball made from latex of rubber trees wrapped around horns and shells. It was not until the 20th century when plastic use became more common *(Quinn et al., 2013)*. Although some discoveries in the 1800s (e.g., vulcanized rubber; polystyrene) were precursors to the plastics we know and use today, it was the beginning of the 1900s that brought the "plastic age." Because of the versatility of plastics, the new "plastic age" was heralded with much enthusiasm:

> *It is a world free from moth and rust and full of colour, a world largely built up of synthetic materials made from the most universally distributed substances, a world in which nations are more and more independent of localised naturalised resources, a world in which man, like a magician, makes what he wants for almost every need out of what is beneath and around him.* (Yarsley & Couzens 1945, p. 152)

During World War II, plastics took a central role in military use, heralding a "plastic revolution." Starting in the 1950s, plastic producers shifted to the consumer market, embarking on a massive public campaign to win consumer hearts and minds with new products like Tupperware, Formica tables, Fiberglass chairs, Naugahyde love seats, hula-hoops, disposable pens, silly putty, and nylon pantyhose. By 1960, the use of plastic surpassed that of aluminum. The adoption of plastics by society for a wide variety of common uses may have occurred because of their functional and adaptable properties. Plastics are inexpensive, lightweight, strong, durable, corrosion-resistant materials, and have high thermal and electrical insulation properties. The diversity of polymers and the versatility of their properties allow them to be used to produce a vast array of products that have myriad societal benefits.

Key Events in the History of Plastics

A timeline of some key events in the history of plastics.



1960

1960s
Polyester becomes the least expensive type of cloth and becomes the most commonly used fabric in clothing.

1965
Kevlar developed at DuPont by Stephanie Kwolek.

1973
Nathaniel Wyeth patented polyethylene terephthalate (PET) plastic. PET bottles were designed to withstand the pressure from carbonated drinks.

1977
Plastic bags are introduced to the grocery industry as alternatives to paper bags.

1988
The Resin Identification Code was invented by the Society of the Plastics Industry.

1988
First plastic money issued in Australia.

2000

2008
China bans plastic bags.

2012
San Francisco becomes the first city in the United States to ban plastic bags.

2014
California became the first state in the United States to ban single-use plastic bags in stores. Today, stores charge a 10-cent fee for single-use plastic bags and paper bags.

2018
Seattle became the largest U.S. city to ban plastic single-use straws.

2020

2025
McDonald's plans to source all packaging worldwide from sustainable sources.

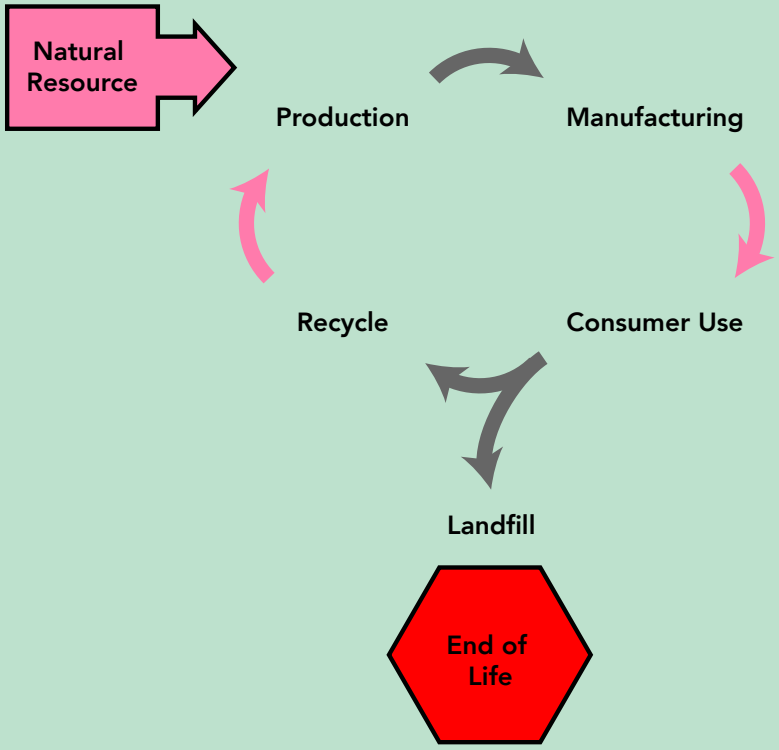
Background Information for the Facilitator (Continued)

Even though plastics are invaluable for many purposes in modern life, the production and post-use of these items must also be taken into consideration. First, the raw materials for plastics (e.g., oil) must be extracted from their source, and this has associated financial costs and environmental impacts, such as leaving large **carbon footprints**. Secondly, the raw materials must be fashioned into a usable item, which also has a monetary cost and environmental impacts. Once plastic items have been used for their intended function, they have a varying post-use life. Some may be recycled, others may be reused, but many are simply discarded. Each of these post-use pathways has an environmental impact – positive and/or negative. Because most plastics have been developed with minimal thought for their ultimate disposal, there are increasing concerns that must be addressed with respect to the environmental consequences when these materials are discarded.

The data surrounding the environmental impacts of plastic show very high rates of carbon emissions as a result of plastic production. However, when looking at plastic alternatives, some research indicates that the carbon footprint of alternative products like glass or aluminum are also high. It is important to understand the **life cycles** (see diagram) of different products, to help make informed decisions as a consumer. Raw materials are first extracted from the Earth, then these materials are processed. After being processed, the products are manufactured and distributed to retail outlets to be purchased by consumers. After consumers use a product, they then make the choice to either **dispose** of, **recycle**, or **repurpose** the item. If they choose to dispose of an item, it ends up as solid waste in a **landfill**; if they choose to recycle, the item enters back into the life cycle at a different point and is reprocessed to make new items; and repurposing finds an alternative use for the item. **Note**: Not all plastic materials are recyclable. For those plastics that can be recycled, they may only be recycled one or two times, and are often downcycled into materials of lesser quality or value.

Background Information for the Facilitator (Continued)

LIFE CYCLE OF MATERIALS DIAGRAM



The **Youth as Change Agents** part of this module is designed to engage youth in transforming plastic impact ideas into actionable projects. 3 5 Youth will work together to ask critical questions about our use of plastics based on their polymer science learning and discussions. Using an inquiry-based learning approach that best fits your program, youth will:

- Develop and implement an action project focused on a specific plastic issue.
- Gain knowledge, skills, and confidence to effectively serve as change agents around plastic related issues.
- Learn from other change agents, both youth and adults, who are working to solve the environmental challenges of plastics.

3 SciGirls

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

5 SciGirls

STEM is collaborative, social, and community-oriented

Polymer Science Inquiry

In this section of the module, youth will explore polymer science content through a guided inquiry activity. Each activity:

- Addresses issues in sustainability and the impacts of plastics.
- Engages youth in science and engineering practices.

If time and interest allow, facilitators can select additional polymer science exploration activities from the Polymer Science Exploration Grid located in the Front Matter Facilitation Tools.

Activity: Pitch Your Material

Youth prepare and deliver a marketing pitch to a fictional beverage company for a beverage container made from their assigned type of material (plastic, aluminum, or glass) using scientific information and a life cycle assessment. Youth will reflect as a large group on the advantages and disadvantages of each type of material.

Facilitator Opening Questions/Prompts (5-10 minutes)

Lead a conversation to anchor learning in youth's past experience with plastics.

- Discuss what you believe are the most common beverage containers people use and why that might be.
- Discuss your understanding of the materials used in packaging beverage containers for your favorite soft drink, juice, or water.
- Explain what type of materials – glass, aluminum, or plastic – you prefer when purchasing beverages. [1]

Facilitator Tip
To enhance the activity, consider providing example containers made from aluminum, plastic, and glass.

[1] SciGirls
Connect STEM experiences to lives

PROCEDURE 1 (EXPERIENCING) (15-25 MINUTES)

1. Organize youth into small groups of two to four. 5 Assign each group one of the three materials: aluminum, glass, or plastic.
2. Provide each group with a blank life cycle chart (Appendix A-1) and a set of life cycle cards (Appendix A-2).
3. Provide each group with the graph of the historical trends relative to the use of aluminum, glass, and plastic (Appendix B). Ask the youth to review the graph.

Facilitator Tip
For those unfamiliar with a line graph, inform them that each point on the graph represents the total weight of a product that was manufactured in the year with which the point lines up on the horizontal axis. The data are presented in thousands of tons. For reference: 1 ton = 2000 pounds (for example: a small car, polar bear, or horse). 1,000 tons = 2,000,000 pounds (for example: small fishing boat, 148 elephants, 10 blue whales).

4. Ask groups to complete the life cycle chart using the information provided.
5. Invite groups to share their complete life cycle chart and explain their reasoning behind where they placed the life cycle cards.

PROCEDURE 2 (EXPERIENCING) (45-60 MINUTES)

6. Present the following scenario to the youth: each pair/small group is a manufacturing company that produces a beverage container using a specific material: glass, plastic, or aluminum. Based on the information they learn about the material they are assigned, each group will prepare and present a sales pitch to a new beverage company – TopFlite Nutri Water – as to why their material is best as a beverage container.
7. Hand out the information sheets on each type of material to each group (Appendix C 1, C-2, C-3). Be sure to provide all three sheets to every group so they have information on the other group's materials.

5 SciGirls

STEM is collaborative, social, and community-oriented

Facilitator Tip
Encourage youth to use their completed material life cycle chart from Procedure 1.

8. Ask groups to: Develop a sales pitch (2-3 minutes in length) using the data from the graph (Appendix B) and the three information sheets (Appendix C). Describe your material's advantages and ways to overcome potential disadvantages of its use. Include a short description of evidence that supports each point. Sales pitches may include why your material is more advantageous than other materials in certain ways.

Science and Engineering Practices
Point out to youth that they will be analyzing and interpreting data, communicating information, and engaging in an argument based on evidence, three of the practices scientists and engineers engage in.

Facilitator Tip
To help strengthen engagement, provide flip chart paper, markers, or other art materials and/or props for youth to use in their pitch. Invite them to be creative!

Encourage groups to propose solutions to make the current disadvantage of the product more advantageous. For example: (1) water bottles might make the cap smaller to reduce plastic use in their production; (2) a glass container might be designed to be converted to at-home glassware; or (3) only use recycled aluminum to manufacture new beverage containers and thus not needing to use newly mined aluminum.

Another idea might be for groups to describe an incentive on each bottle or can that includes a hashtag to use social media to document the consumer's recycling of the product.

9. Give groups 25 to 30 minutes to review the information sheets and prepare their sales pitch. Facilitator Tip: You may want to spend time with each group; if needed, offer ideas or answer questions youth may have.

10. Allow each group to present their sales pitch in front of the full group

11. If time permits, you may engage in a second iteration where groups have 5 minutes to prepare a counterargument to the other groups' claims about their material and offer another pitch.

Science and Engineering Practices
In this activity youth are evaluating information, a science and engineering practice.

REFLECTION: SHARE, PROCESS, GENERALIZE (10-15 MINUTES)

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. 3

- Describe what you learned about plastics, aluminum, or glass materials.
- Describe and compare the trends you observe in the production of glass, plastic, and aluminum.
- What do you predict the trends in material usage will look like in years: 10 years? 20 years? Why do you think this will happen?
- Explain what would influence your decision to purchase a specific type of beverage container made from plastic, aluminum, or glass.
- Describe what you think other alternatives there are to purchasing beverage containers in glass, plastic, or aluminum.

Science and Engineering Practices
This discussion will help youth consider additional solutions, a science and engineering practice.

CONCEPT/TERM DISCOVERY

At this point, it is important to ensure that the terms **aluminum, carbon footprint, disposal, glass, landfill, life cycle, plastic, recycle, repurpose,** and **trend** have been discovered by or introduced to the youth. The goal is to have the youth discover terms and concepts on their own, defining and sharing them with their own words. If youth haven't already shown their knowledge of those concepts, revisit these ideas in a guided discussion.

2 SciGirls

Support as they investigate using STEM practices

3 SciGirls

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

Youth as Change Agents

In this portion of the module, youth will turn their polymer science learning and plastic impact ideas into an actionable project. Youth will plan and implement an action project that reflects their questions related to plastics. Through this process, youth will gain knowledge, skills, and confidence to effectively serve as change agents around a plastic related issue. 2 3

Background Information for the Facilitator

Facilitators will guide youth through the process of developing an action project. Youth could choose a series of mini action projects or one in-depth action project. Outlined below are key learning and guiding questions for each step.

The action steps include:

1. Discovering the action project
2. Planning the action project
3. Putting the project into action
4. Sharing and reflecting on the action project

2 SciGirls

Support as they investigate using STEM practices

3 SciGirls

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

WAYS TO APPROACH THE ACTION PROJECT

The approach you choose will vary depending on the plastic issue youth want to address. For example, youth may want to study microplastics in the local waterway and collect data to contribute to a scientific study to help inform the public. This action project could use a citizen science approach **or** geo-inquiry approach, depending on the goals of your group. Youth may want to:

- Conduct a scientific investigation including data collection and analysis.
- Embark on an action project to improve a condition in their school or community.
- Start an advocacy campaign to change a condition or policy.

The Change Agent Approach Matrix included in the Front Matter is a guide to help determine the best approach to address the group's question or chosen plastic issue. Here is a brief description of each approach:

- **Citizen science** – an approach where youth collect data which is shared with the professional scientific community to study real-world phenomena.
- **Geo-inquiry** - an approach where youth analyze space, place, and human conditions through maps usually with the aid of geographic information systems (GIS).
- **Community engagement** – an approach where youth get involved in an organized effort on behalf of another government or nonprofit organization to benefit the community.
- **Service learning** – an approach where youth develop a project to benefit others and their community. Service learning can be a direct-service, indirect service, or advocacy-based service project that does not include data collection.
- **Youth participatory action research (YPAR)** – an approach where youth define an issue and research question, conduct an investigation (data collection, analysis), and then take action based on the results. In YPAR, youth develop a project where they collect and analyze data, followed by a service-learning project informed by their data outcomes.

PROCEDURE

Facilitate a group discussion to help youth ask critical questions about our use of plastics. You may choose one or more of the questions below to help guide youth in connecting concept understanding to taking action. Record youth's observations, questions, and discussion on flip chart paper. This discussion will help ground youth in the larger issues as they move into discovering their action project.

- What do we care about regarding our world's use of plastics and their impact? 1
- Describe your reasons for why people should continue or change their behavior around their use of aluminum, glass, and plastic
- Imagine a perfect future. What does plastic use and disposal look like?

Science and Engineering Practices
Youth engage in defending your viewpoint by stating evidence or reasons, a science and engineering practice.

Lead youth through the key core learning experiences for steps 1-4 using the guiding questions.

Step 1

DISCOVERING THE ACTION PROJECT

Youth generate, discuss, advocate, and select a handful of issues or questions to explore.

The goal is to have students contribute to something larger than themselves and achieve broader impact.

Science and Engineering Practices

Youth engage in asking questions and/or defining problems, a science and engineering practice.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Discovering the Action Project • Youth ask questions and discuss issues related to plastics. • Youth brainstorm/generate ideas for a project/plan to address the issue. • Youth record ideas. • Youth identify what additional information is needed to select a project/plan. • Youth determine ways to address/ solve the issue. 2 • Youth will identify how the project will make a positive change. • Youth select a project.	**Discovering the Action Project** • What do we already know about plastics in our community/world? • What do we wonder about plastic use and the environment? • What information do we need to know about plastics in our community or world (research)? • What critical issue related to plastic use and its environmental impacts do we want to address? • What action can we take to answer or address the question or issue? • How does what we learned about polymers influence how we want to take action?

2 SciGirls

Support as they investigate using STEM practices

Facilitator Tip
Highlight scientists and change agents who are currently working to address real life plastic issues using different approaches. Facilitators can showcase a video from the NSF Center for Sustainable Polymers (https://csp.umn.edu/) or read about innovators transforming the way we use plastics and the way plastics are made. 6 See the Change Agent Approach Matrix included in the Front Matter for examples.

6 SciGirls

Interact and learn from diverse STEM role models

Step 2

PLANNING THE ACTION PROJECT

Youth plan and prepare the various steps of the action project in order to be successful.

The goal is for youth to gain project planning skills of organizing tasks, determining resources needed, and creating a project timeline.

Science and Engineering Practices

Scientists and engineers also use this practice of planning their investigation.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Planning the Action Project • Youth discuss and determine project goals. • Youth identify resources. • Youth create action steps/data collection plan to guide the project. • Youth determine who will do what by when.	**Planning the Action Project** • What do we want to achieve in this project? • What skills do we need to accomplish this project? How could we gain them? Who can help? • Who can we invite to partner with us on planning the project? (elected officials/government representatives, businesses, schools or non-profits)? 5 • What steps do we need to take to achieve this goal? • What resources do we need to help us achieve our goal? • What is our timeline - which activities will we do by when? • What are the roles for our group members (who will do what when)? 5 • What else do we need to know to help us be more prepared for this project?

Facilitator Tip
Change Agent Project Planning Tool can be used when developing a detailed project plan (see Front Matter).

Facilitator Tip
During the planning of the action project (step 2), youth should identify a range of people in the community that can support their action project. Before reaching out to community members, guide youth as they craft written correspondence, social media posts, and in-person interactions with community members. This will help youth develop and grow their communication skills and gain confidence. Please see the Front Matter for additional resources to support youth in developing their communication skills.

Step 3

PUTTING THE PLAN INTO ACTION

Youth engage in final project preparation steps and then experience carrying out their action plan.

The goal is for youth to gain confidence through project implementation to effectively serve as change agents and engaged citizens around issues of plastics.

Science and Engineering Practices

Carrying out their planned investigation is a science and engineering practice. 3

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Putting the Plan into Action • Youth implement an action plan. • Youth share project impact/project research. • Youth determine project sustainability.	**Putting the Plan into Action** • What final preparation steps do we need to take in order to implement the plan? • Are there additional people we can invite as we put the plan into action - peers, family members, community members, leaders, others? 5 • How will we record what we did? • How will we share the results of our work? Is it already part of the project (for example, in a citizen science project protocol)?

3 SciGirls

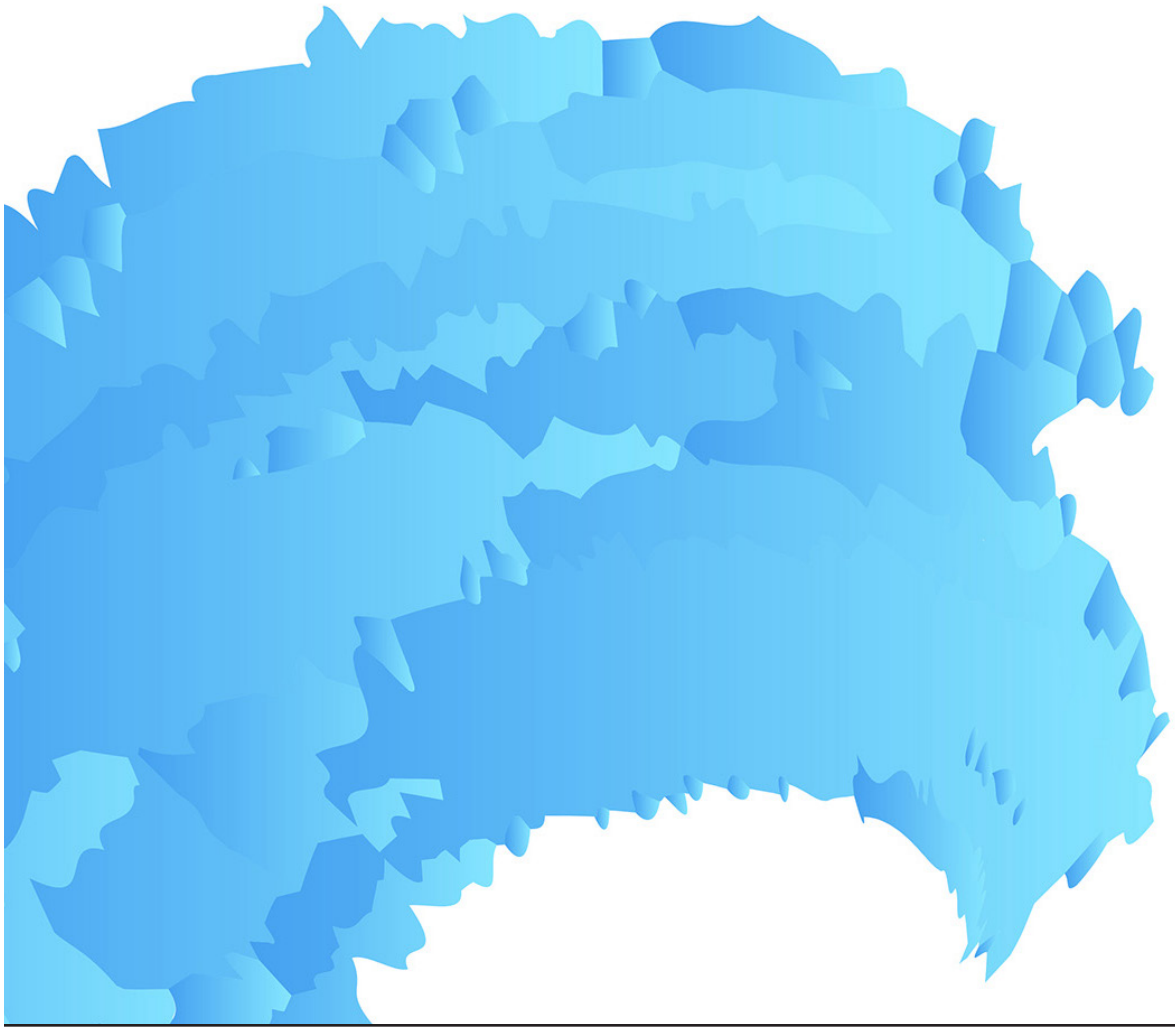
Embrace struggle, overcome challenges, and increase self-confidence in STEM

5 SciGirls

STEM is collaborative, social, and community-oriented

Facilitator Tip
Governmental departments, elected officials, and businesses may be eager to support your action project, especially if it aligns well with their mission and goals. They may offer hands-on support of the project (setting up a tour of the local recycling center or a recycling business).

Facilitator Tip
Be sure to take pictures or video during the action project or designate a youth or adult to be the photographer.



Step 4

SHARING AND REFLECTING ON THE ACTION PROJECT

Youth reflect on the action project and share results (e.g., presentations; videos; newsletter/newspaper articles) with peers, community leaders, members of their communities, and other venues.

The goal is for youth to evaluate the project impacts, both on the community and on their own experience.

Science and Engineering Practices

Several science and engineering practices occur in this step, including analyzing and interpreting data, constructing explanations or designing solutions, engaging in argument based on evidence, and communicating information.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Sharing and Reflecting on the Action Project • Youth analyze and evaluate the project's impact. • Youth reflect on personal learning. • Youth publicly showcase the project. • Youth share results with community and stakeholders. • Youth celebrate project impact and personal contributions.	**Sharing and Reflecting on the Action Project Youth Learning:** • Why did we choose this project? • What was our main goal? What did we accomplish? • What ways did we impact the plastic issue in our community/world? • What could the future of this action/ project look like? • Are there new questions or ideas? • If we were to do this project again, what would we do differently? • Who else can we share our actions/ finding with? • How might we or the community continue elements of the project? • What do you think would happen if more people did this same project?

GUIDING QUESTIONS (CONTINUED)

Youth Leading:

- What did we learn?
- What skills did we gain?
- What was our favorite part of the project?
- What was the hardest part of the project? 3
- How do we feel about what we accomplished in the project?
- How do we feel about how our group worked together during the project?
- What leadership skills did we gain through the project?
- What communication skills did we gain as a result of our project?

Celebrating:

- Who helped us along the way? How should we thank them? 5
- Who else can help elevate and share our actions and findings? How can they help us continue our efforts?
- How can we all celebrate together?

3 SciGirls

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

5 SciGirls

STEM is collaborative, social, and community-oriented

Facilitator Tip
Use the Change Agent Action Project Evaluation sheet (see Front Matter) to evaluate the outcomes and impact of the action project as well as reflect on personal skills gained through the process. Personal reflection can also include writing, pictures, charts, or other expressions that assess the impact of the project. Create an opportunity for group reflection.

Facilitator Tip
Celebrating provides an opportunity to publicly recognize positive achievements and personal growth of youth. Depending on time available, offer a public showcase of what youth learned and accomplished during the action project. If time is limited, provide certificates of recognition.

CONGRATULATIONS CHANGE AGENTS!

Through the Youth as Change Agents experience, youth addressed the complex issues of plastics in our communities, our country, and our world. Youth gained valuable leadership skills by planning and implementing a plastic focused action project reflective of their interests and passions. They successfully served as important change agents and engaged community members to imagine a new future of plastics. Please be sure to share your action project via #4HSolvetheChallengeofPlastics.

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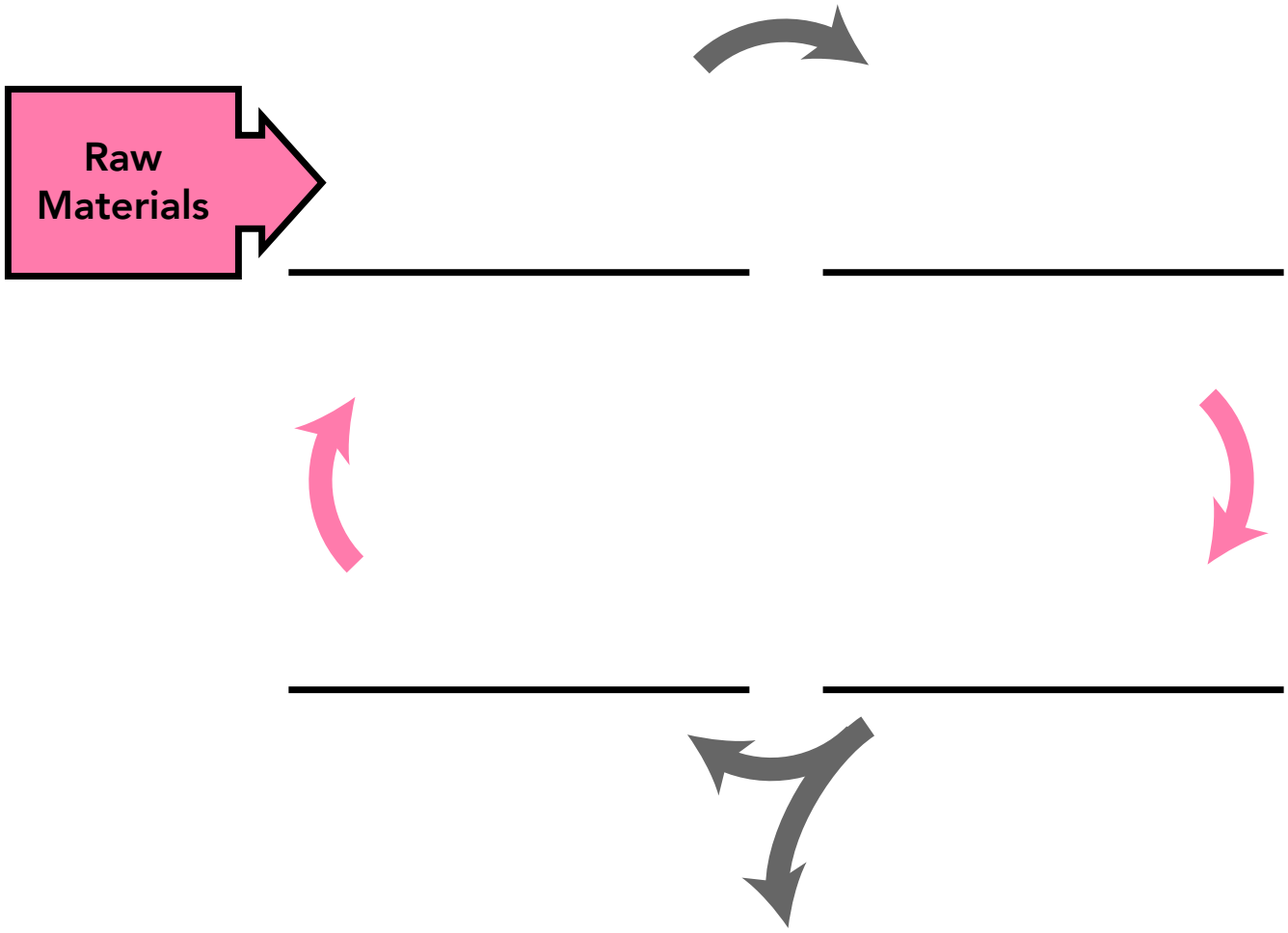
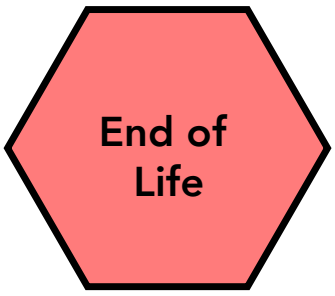
Appendix A-1

Blank Life Cycle



More than one card can be placed per line



Appendix A-2

Life Cycle Cards

Extraction

Raw materials are withdrawn from the Earth

Manufacturing

Process of making products with raw materials using power and machinery

Transportation

Product is transported to stores, restaurants, and warehouses

Consumer Use

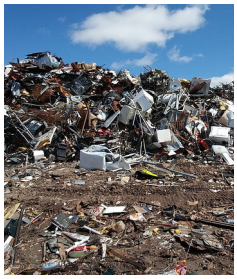
People purchase product and use it

Disposal

the action of throwing away or getting rid of something

Landfill

site where trash is taken



Recycle

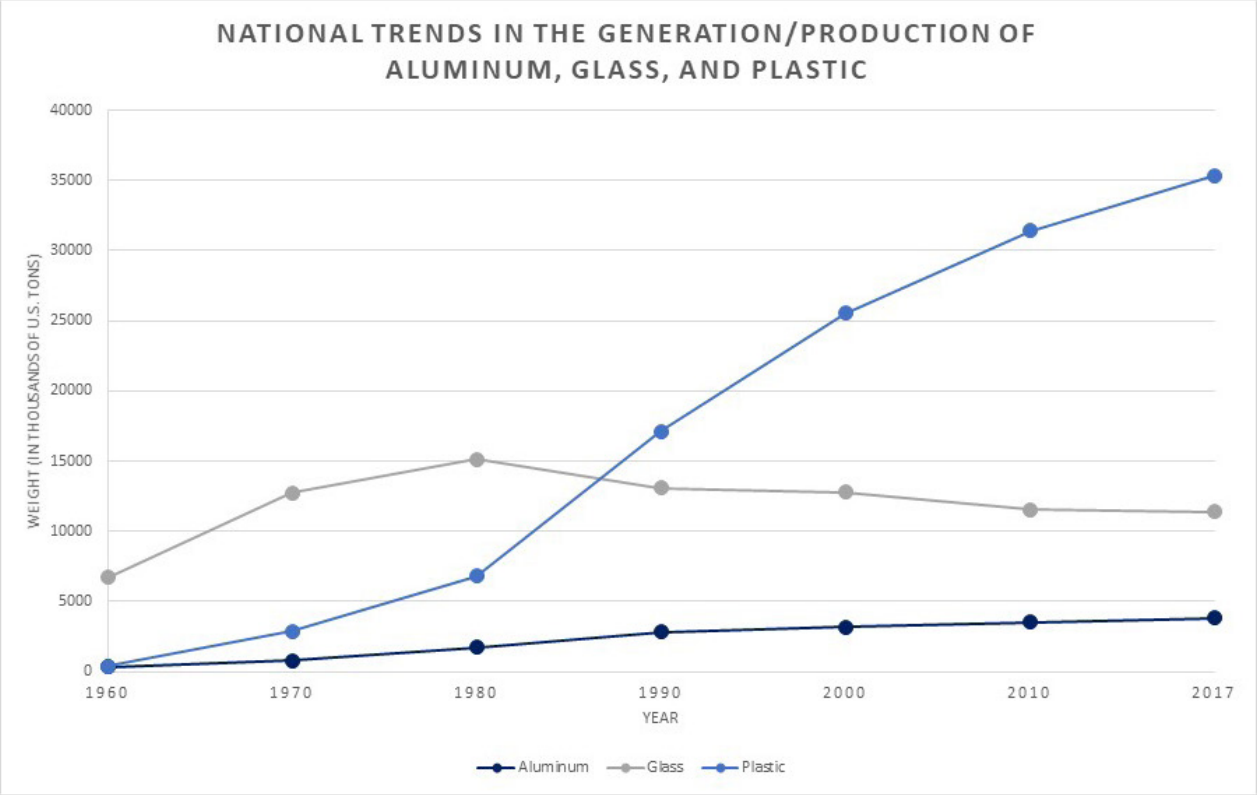
process of converting waste materials into new objects

Repurpose

adapting for use in a different purpose

Appendix B

National Trends in Aluminum, Glass, and Plastic Generation/Production



The data are presented in thousands of tons. For reference:

- 1 ton = 2000 pounds (for example: a small car, polar bear, or horse)
- 1,000 tons = 2,000,000 pounds (for example: small fishing boat, 148 elephants, or 10 blue whales).
- On the graph, 20,000 tons would weigh as much as 200 blue whales.

Glass: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/glass-material-specific-data
Aluminum: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/aluminum-material-specific-data
Plastic: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data

Data accessed from: Environmental Protection Agency Material-Specific Data for Glass, Aluminum and Plastic (www.epa.org)

Appendix C

Material Information Sheets for Aluminum

Prepare and present a sales pitch to a new beverage company – TopFlite Nutri Water – as to why aluminum is best for them to use as a beverage container.

Describe aluminum's advantages and ways to overcome potential disadvantages of its use. Include a short description of evidence that supports each point. Sales pitch may include why aluminum is more advantageous to plastic and glass in certain ways.

ALUMINUM

A light silvery-gray metal commonly used for beverage containers and foil wrap.

Extraction

- Aluminum is found in a clay-like rock. It is mined in tropical and subtropical areas of the world.
- The mining process often involves cutting down entire forests.
- The energy used to create aluminum causes air pollution (greenhouse gas emissions) and water pollution (in streams, ponds and lakes, and groundwater).
- Aluminum is considered a non-renewable resource because it is available in limited quantities.

Manufacturing

- Metal is transported to the processing plant. Transportation releases greenhouse gasses.
- Fossil fuels are burned for energy during manufacturing, resulting in air pollution.
- The scrap aluminum can be used to make cans for beverages.
- The use of the excess aluminum and recycled aluminum cans can reduce the use of fossil fuels, making it more environmentally friendly.

Consumer Use

- Aluminum cans are lightweight and durable.
- Once the aluminum beverage containers have been produced and filled with your favorite soft drink or water, the cans are brought to your local supermarket or vending machine.

Disposal

The choice we make on how we dispose of an aluminum can determines its fate.

- **Trash**: Cans are brought to landfills when they are discarded in the garbage bin. Although some materials, such as food scraps, decay in the soil quite readily, aluminum cans may take more than 100 years to decompose. Additionally, there are other problems associated with landfills, including surface water pollution (e.g., streams, lakes, and ponds), groundwater pollution, and production of the greenhouse gas methane.
- **Recycle**: Recycling aluminum means they can be made into new cans. This is great because aluminum can be recycled indefinitely. US recycles on average 16% of aluminum.
- **Repurpose**: Repurposing aluminum cans involves thinking of other ways to use them. For example, the tops of aluminum cans can be removed and then used as storage containers in a workshop to hold nails or screws. By repurposing an aluminum can, it is not only being recycled, but also reducing waste in the landfills.

Appendix C-2

Material Information Sheets for Glass

Prepare and present a sales pitch to a new beverage company – TopFlite Nutri Water – as to why glass is best for them to use as a beverage container.

Describe glass's advantages and ways to overcome potential disadvantages of its use. Include a short description of evidence that supports each point. Sales pitch may include why glass is more advantageous to plastic and aluminum in certain ways.

GLASS

A hard brittle and transparent substance made from sand commonly used to make windows and containers.

Extraction

- The most commonly used glass is made from the raw materials sand, limestone, and soda ash.
- Large amounts of greenhouse gasses are emitted into the atmosphere during extraction.
- After the raw materials are processed, they are transported to a manufacturing facility. Transportation releases greenhouse gasses.

Manufacturing

Once raw materials reach the manufacturing facility, they go through a four-step process and each stage requires fossil fuels which releases greenhouse gasses. Fossil fuels are burned for energy during manufacturing, resulting in air pollution.

1. The sand, limestone, and soda ash are mixed together.
2. The mixture goes through a furnace to be melted and refined. At this stage, the highest amount of greenhouse gases is released into the atmosphere.
3. The glass is then shaped and formed. Forming helps to shape the glass.
4. Finally, the glass goes through a final forming process to make the final product.

Disposal

The choice we make on how we dispose of a glass bottle determines its fate.

- **Trash**: Glass is brought to landfills when they are discarded in the garbage bin. Landfills are disposal areas where solid waste is buried and covered with a layer or two of soil. Since glass is such a sturdy material, it can take millions of years to decompose in a landfill. Additionally, there are other problems associated with landfills, including surface water pollution (e.g., streams, lakes, and ponds), groundwater pollution, and production of the greenhouse gas methane.
- **Recycle**: Glass bottles are 100% recyclable. Recycling glass bottles helps conserve energy when compared to the first manufacturing process of the raw materials. Recycled glass also has a lower melting point, therefore, reducing the energy needed to melt the glass during the manufacturing process. US recycles on average 27% of glass.
- **Repurpose**: Choosing to repurpose glass involves thinking of new ways to use the product. Glass bottles are commonly used as flower vases and for other decorations.

Appendix C-3

Material Information Sheets for Plastic

Prepare and present a sales pitch to a new beverage company – TopFlite Nutri Water – as to why plastic is best for them to use as a beverage container.

Describe plastic's advantages and ways to overcome potential disadvantages of its use. Include a short description of evidence that supports each point. Sales pitch may include why plastic is more advantageous to glass and aluminum in certain ways.

PLASTIC

A type of material that can be molded into solid objects and is usually made from petroleum/oil.

Extraction

- Plastic is composed of polymers, or large molecules made of smaller monomers, and historically made from oil (including petroleum and natural gas). Some are now made from renewable materials (such as corn, potatoes, or cotton).
- Petroleum is removed from underground and refined into a variety of materials. There can be negative side effects for animals, humans, and the environment from extracting oil.
- Oil is considered a non-renewable resource because it is available in limited quantities and takes a long time to be replenished (i.e. millions of years).

Manufacturing

- Oil is transported to the manufacturing plant. Fossil fuels are burned for energy during manufacturing, resulting in air pollution
- Manufacturing involves creating the plastic resin and then making it into bottles.
- Empty bottles must then be transported to the processing plant to be filled with the liquid beverage. Plastic weighs less than glass, so transportation emits less greenhouse gasses.

Consumer Use

- Plastic beverage containers are lightweight and durable.
- Once the plastic beverage containers have been produced and filled with your favorite soft drink or water, the bottles are transported to your local supermarket or vending machine.

Disposal

The choice we make on how we dispose of an aluminum can determines its fate.

- **Trash**: Plastics are brought to landfills when they are discarded in the garbage bin. Plastic materials can take hundreds to thousands of years to decompose because most are not able to break down and decompose. Additionally, there are other problems associated with landfills, including surface water pollution (e.g., streams, lakes, and ponds), groundwater pollution, and production of the greenhouse gas methane.
- **Recycle**: US recycles on average 8% of all plastic; however, around 30% of plastic bottles are recycled. Recycled plastics are sorted at a recycling plant, then sent to a reprocessing plant where they are made into new materials. Plastics are made from different types of polymers and must be processed differently. While some containers are made from a single type of plastic, others are made of multiple plastic types and are much more challenging to recycle.
- **Repurpose**: Plastic bottles may sometimes be used for other purposes.

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

NATIONAL
PEER REVIEWED

MODULE
2
GRADES 6-8

Sustainable Polymers

Taking Action to Solve the Challenge of Plastics

A 4-H STEM Curriculum for Grades 6-8

National Science Foundation

NSF Center for Sustainable Polymers

4-H Polymer Science Curriculum for

Grades 6-8

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 note where the science and engineering practices are used. 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

Facilitator Tips

These tips provide strategies and helpful suggestions for facilitators.

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

The Plastic Present: Inescapable Impacts of Polymers

Driving Questions:

- **What happens to all the plastic we continue to consume?**
- **What impact do plastics have on the environment, and what can we do to protect plants, animals, and the environment?**

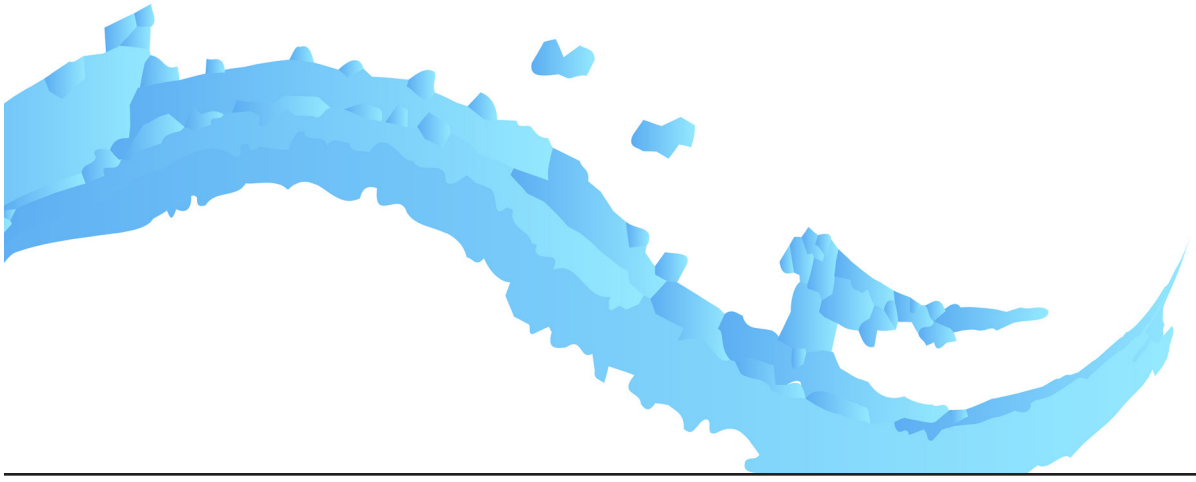
Introduction

MODULE SUMMARY

In this module, youth will determine how disposal choices of plastics impact the environment. Participating in a human-sized board game, small groups will start at the Grocery Store and follow the lifecycle of a plastic water bottle as determined by a consumer. Afterward, youth will reflect on this experience to create a youth-driven action project.

Time Required: 2+ meetings depending on youth-driven action project

- Set up for activity: 10 minutes
- Polymer Science Inquiry Activity: Confessions of a Plastic Water Bottle (35-50 minutes)
- Youth as Change Agents Activity: Youth-driven projects (varies, 60-120 minutes)



Module Focus

LEARNING OBJECTIVES	• Youth will be able to identify the pervasive nature of plastics. • Youth will be able to identify examples of where they could find, use, and dispose of sustainable polymers in their community and everyday life. • Youth will analyze how plastics impact the environment positively and negatively. • Youth will engage in personal disposal actions that will have a positive impact on the environment.
SCIENCE & ENGINEERING PRACTICES (NGSS) 2	• Asking questions and defining problems. • Developing and using models. • Planning and carrying out investigations. • Constructing explanations and designing solutions.
CONCEPTS & VOCABULARY	• **Biodegradable**: capable of being decomposed by bacteria and other microorganisms • **Bioplastic**: polymers often made from starch-containing plants, such as corn and potatoes. Many of these bioplastics are compostable. • **Change agent**: youth leaders who transform their ideas into actionable projects to create positive social impact.

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Module Focus (Continued)

CONCEPTS & VOCABULARY

- **Industrial compost facility**: site where organic waste products go through a multi-step process converting items into usable soil.
- **Landfill**: site where waste from the community is taken.
- **Life cycle assessment**: evaluates the environmental impacts of the extraction of raw materials; manufacturing of the product; the transportation of the product; the use of the product by the consumer; and the disposal or recovery of the product.
- **Litter**: items not disposed in recycling, compost, or trash receptacles are instead disposed of in the environment.
- **Microplastics**: tiny pieces of plastic.
- **Non-renewable resource**: resources that are only available in limited quantities and take a long time to be replenished (i.e. millions of years).
- **Petroleum**: oil extracted from the earth that can be used for fuel or made into plastic.
- **Pollution**: contamination by waste, chemicals, or other harmful substances to an environment.
- **Polylactic acid (PLA)**: a specific type of bioplastic derived from plant materials, usually corn.
- **Polymers**: chemical compounds consisting of long repeating chains of smaller molecules.
- **Recycle**: process of converting waste materials into new objects.
- **Refuse**: decline to use an item and identify alternatives.
- **Repurpose**: use an object for a new purpose other than it was originally intended.

Module Focus (Continued)

CONCEPTS & VOCABULARY	
	• **Reuse**: find a way to use again; or sell/donate for another to use. • **Single-use**: an item that is thrown away after being used only once.

Facilitator Preparation

MATERIALS NEEDED

SET-UP

- ☐ Room Set-Up (Appendix A) for the Facilitator.
- ☐ Plastic Selection cards (Appendix B): print, duplicate as needed, and cut along dotted lines. (Option: Instead of paper cards, consider using more tactile objects like plastic bottles and PLA cups).

STATION 1: THE GROCERY STORE

- ☐ Station Sign, Station Directions (Appendix C)
- ☐ One Die

GETTING READY

- Suggested groupings: 2-3 youth.
- Organize the learning stations as suggested in Appendix A.
- Make copies of Appendices B-J and gather materials to place at the respective learning stations. Print pages single-sided if cutting apart.
- Use the information on the left, and the information in the Appendices B-J to set up individual learning stations.
- Consider laminating the observation sheets (Appendix D) or providing small whiteboards and giving youth dry erase markers to record their notes.

Facilitator Preparation (Continued)

STATION 2: LANDFILL

- ☐ Station Sign, Station Directions (Appendix D)
- ☐ Observation Sheet (Appendix D): print, duplicate as needed.
- ☐ One used and cleaned plastic bottle per youth.
- ☐ Scissors
- ☐ Container labeled "landfill" to use to collect scrap pieces of plastic bottles.

Facilitator Preparation (Continued)

STATIONS 3-6: RECYCLING CENTER, INDUSTRIAL COMPOST FACILITY, REUSE, AND LITTER

- ☐ Station Signs, Station Directions (Appendix E - H)
- ☐ Cards provided in Appendix E-H (print, duplicate as needed, and cut along dotted lines) Crumble up Appendix H cards to look like litter.

STATION 7: REPURPOSE

- ☐ Station Signs, Station Directions (Appendix I)
- ☐ Cards provided in Appendix I (print, duplicate as needed, and cut along dotted lines)
- ☐ Markers, pens, pencils crayons, colored pencils, or other basic art supplies

Facilitator Preparation (Continued)

STATION 8: THE OCEANS

- ☐ Station Sign, Station Directions (Appendix J)
- ☐ Plastic Pledges handout (Appendix J) Consider making the or consider making Plastic Pledges into a large poster.
- ☐ Pencils

YOUTH AS CHANGE AGENTS

- ☐ Flip chart paper
- ☐ Markers
- ☐ Copy of Change Agent Approach Matrix - see Front Matter Facilitation Tools

YOUTH AS CHANGE AGENTS

- ☐ Review Change Agent Approach Matrix in Front Matter Facilitation Tools
- ☐ For tips on supporting open discussion and collective decision making, see Front Matter Facilitation Tools for active group facilitation strategies.

Background Information for the Facilitator

Plastics are a part of our everyday lives. From food containers, to toys, to computers, plastic is one of the most widely-used materials in society. While they are helpful in making life simpler, the effects of plastic on humans, animals, and the planet can be detrimental. Since the 1950s, it is estimated that over one billion tons of plastic have been discarded. Plastic trash that does not get disposed of properly often ends up as **litter** in the environment. Among the many concerns regarding plastic waste, their effect on marine organisms is the most harmful and incalculable. Plastics may entangle marine animals. **Microplastics**, tiny pieces of plastic, can harm organisms in an ecosystem. Somewhere between 50 to 80% of ocean debris is plastic. Plastics in the environment can also release harmful chemicals that may find their way to water sources. For both animals and humans this type of **pollution** can result in illness. For example, some plastics are prepared using Bisphenol-A (BPA), a compound that has been show to disrupt normal hormone function in animals. How people feel about and use plastics is changing because of these challenges *(Thompson, Moore, vom Saal, & Swan, 2009, p. 2162*).

Some plastics are made from synthetic polymers, meaning they are created from chemical means. These plastics are usually made from **petroleum** oil, a **nonrenewable resource**, which can take hundreds to thousands of years to decompose. It takes even longer when plastic is buried with other trash in **landfills**. Some plastic materials are intended for a **single use**. After their intended use, the materials are often disposed of. Finding the most responsible disposal choice for plastics can be tricky.

We can reduce our dependence on petroleum-based plastics by refusing to purchase petroleum plastic products, **recycling, reusing, repurposing**, in combination with choosing bioplastics made from renewable resources.

Refusing and reducing the amount of plastic used and consumed can help decrease the amount of plastic waste. **Refusing** is saying "no" to products with plastic and instead purchasing products that do not contain plastic (e.g., using a metal water canteen instead of taking a disposable plastic water bottle). Other methods to decrease the amount of plastic waste are **reusing** or **repurposing**. In fact, reusing old materials is easy to do at home! By repurposing a tissue box into a pen holder, or knitting together plastic bags to make a more durable single bag, reusing can be a creative and fun process that helps the environment.

Background Information for the Facilitator (Continued)

Another method to dispose of plastics is to **recycle** them. Recycled plastics are sorted at a recycling plant, then sent to a reprocessing plant where they are processed into new materials. Of all the plastic used for packaging, only 14% is collected for recycling. The greatest challenge to recycling is the difficulty of sorting plastics. Plastics are made from different types of polymers and thus must be processed differently. While some containers are made from a single type of plastic, some are made of multiple plastic types and are much more challenging to recycle. To aid in sorting, the Society of the Plastics Industry, Inc. designed a uniform system to identify various polymer types.

The ***Resin Identification Code (RIC)*** outlines seven numbers to identify the specific polymer (see resin codes 1-7 below and learn more with this recycling guide https://naturalsociety.com/recycling-symbols-numbers-plastic-bottles-meaning/).

Bioplastics are alternatives to petroleum plastics. They are made from renewable resources and some types can decompose through natural processes. **Polylactic acid** (PLA) is a bioplastic made from starches like corn and sugar. This product can be disposed of in an **industrial compost facility**, where it will **biodegrade** in 180 days. However, if PLA doesn't make it to the industrial compost facility, it can take just as long as petroleum plastics to degrade. Because of this, it is vital for these products to be disposed of properly.

Designers interested in sustainability use a technique called **life cycle assessment** to analyze the environmental impacts of products. Life cycle assessment takes into account all stages of a product's life including extracting raw materials, processing, manufacturing, distribution, use, repair, and disposal (often called "cradle to grave"). This broad focus allows designers to consider systematic environmental concerns such as energy use, the impact of extracting raw materials and related potential pollutants, and how the flow of materials affects the environment.

The life cycle assessment includes four main stages (U.S. General Services Administration):

- **Goal Definition**: describe the product and the environmental considerations under review for the assessment.
- **Life Cycle Inventory**: identify and determine the amounts of energy, water, and raw materials used as well as any environmental emissions (air, waste, etc.) in the product life cycle.
- **Life Cycle Impact**: analyze the potential human and ecological effects of the energy, water, raw material usage and emissions.
- **Interpretation**: Evaluate the results of the Life Cycle Inventory and Life Cycle Impact analyses to select the preferred product

Learn more about life cycle assessment:

- Life Cycle Assessment (LCA) Overview from the U.S. General Services Administration Sustainable Facilities Tool: https://sftool.gov/plan/400/life-cycle-assessment-lca-overview
- Explore sustainable design options for building design with the Sustainable Facilities Tool: https://sftool.gov/Explore
- Guidelines for Social Life Cycle Assessment of Products, United Nations Environment Programme: http://www.unep.fr/shared/publications/pdf/DTIx1164xPA-guidelines_sLCA.pdf
- Environmental Benefits Calculator: https://www.natureworksllc.com/Resources/Environ-Benefits-Calc

The **Youth as Change Agents** part of this module is designed to engage youth in transforming plastic impact ideas into actionable projects. Youth will work together to ask critical questions about our use of plastics based on their polymer science learning and discussions. Using an inquiry-based learning approach that best fits your program, youth will:

- develop and implement an action project focused on a specific plastic issue
- gain knowledge, skills, and confidence to effectively serve as change agents around plastic related issues
- learn from other change agents, both youth and adults, who are working to solve the environmental challenges of plastics.

Polymer Science Inquiry

In this section of the module, youth will explore polymer science content through a guided inquiry activity. Each activity:

- Addresses issues in sustainability and the impacts of plastics.
- Engages youth in science and engineering practices.

If time and interest allow, facilitators can select additional polymer science exploration activities from the Polymer Science Exploration Grid located in the Front Matter Facilitation Tools.

Activity: Confessions of a Plastic Water Bottle

Youth participate in a human-sized board game. They begin at the grocery store and explore how their disposal choices impact the lifecycle of a plastic bottle and the environment.

FACILITATOR OPENING QUESTIONS/PROMPTS (5-10 MINUTES)

Lead a conversation to anchor learning in youth's everyday experience with plastics. 1

- Where do you observe plastics in your everyday life? In this room?
- Where have you used plastic today? What plastic have you thrown away in the last 24 hours?
- What happens to that plastic when we are done with it?

PROCEDURE (EXPERIENCING) (20-25 MINUTES)

1. Divide youth into groups of 2-3 people. 5
    a. Explain to the groups that consumers can decide to dispose of plastic in different ways.
    b. Have each group come up one by one and allow one member to reach into a bag or hat to select their random plastic identification: **Bioplastic or Petroleum-based plastic bottle** (Appendix B). As they go through the activity as a plastic bottle, they will discover where different plastics are disposed of after being used.

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2. Start the groups at Station 1: The Grocery Store (Appendix C).

    a. Introduce each station to youth. Invite them to ask any questions they have about each station before they begin.

    b. Let each group roll the die in turn at the Grocery Store station. Groups will proceed to their respective stations as indicated in Appendix C.

    c. As groups complete their bottle's lifecycle, they will be directed to return to the Grocery Store.

Facilitator Tip
Consider having a backup activity ready if some groups have cycled through more quickly than others. For example, you may encourage them to reflect on the strengths and weaknesses of the plastic they received. Alternatively, you could encourage groups to start again by making another random choice from the bag.

3. Each pair/small group will travel through different disposal options of plastic.

    Station 2: Landfill

    Station 3: Recycling Center

    Station 4: Industrial Compost Facility

    Station 5: Reuse

    Station 6: Litter

    Station 7: Repurpose

    Station 8: The Oceans

Facilitator Tip
Encourage youth to place their sketched ideas facedown when moving to the next station. Share each group's ideas at the end of the game rather than during to encourage the most creativity from each youth.

Facilitator Tip
Reflect on the pledges as a whole group after the game is complete. Which activities appear to be a priority for your group? How can this inform your action project?

4. The activity ends when each pair/small group has the experience of cycling through the purchase of a plastic bottle through its use and disposal.

Science and Engineering Practices
As youth go through this activity, they are making analogies to steps in the life cycle of a plastic bottle. This use of a model is a practice of science and engineering.

REFLECTION: SHARE, PROCESS, GENERALIZE (10-15 MINUTES)

Spend some time reviewing observations across small groups and stations with the whole group. 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. 3

For example:

- What did you notice about what happens to a bottle after it is used?
- Less than 10% of petroleum-based plastic gets recycled each year. How did our experience in this activity compare to that recycling rate? To the rate of recycling in our community?
- How does your experience of plastic disposal in this game compare to the options available in your community?
- What do you wonder about the bottle's creation, use, and disposal?
- What are the pros and cons of petroleum-based plastics compared to bio-based plastics?

Science and Engineering Practices
When youth organize data into pros and cons, this is an example of the science and engineering practice of analyzing and interpreting data.

- Share your reasons for why people should or should not change their behavior around plastic use. Defend your viewpoint by stating evidence or reasons.

Science and Engineering Practices
This is an example of the science and engineering practice of engaging in argument based on evidence.

- Describe actions you might consider taking personally, around plastic use. How do you think your actions may impact the challenges that surround plastic use? 1

Facilitator Tip
The concept of this activity is to help youth understand the life cycle of petroleum-based plastic products and bioplastics and their impacts on the environment. The young people's observations and questions will form the basis of the Action Project

CONCEPT/TERM DISCOVERY

At this point, it is important to ensure that the terms **biodegrade, decompose, industrial compost, landfill, litter, non-renewable resource, petroleum, pollution, recycle, reuse, and repurpose** have been discovered by or introduced to the youth. The goal is to have the youth discover terms and concepts on their own, defining and sharing them with their own words. If youth haven't already shown their knowledge of those concepts, revisit these ideas in a guided discussion.

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Youth as Change Agents

In this portion of the module, youth will turn their polymer science learning and plastic impact ideas into an actionable project. Youth will plan and implement an action project that reflects their questions related to plastics. Through this process, youth will gain knowledge, skills, and confidence to effectively serve as change agents around a plastic related issue. 2 3

Background Information for the Facilitator

Facilitators will guide youth through the process of developing an action project. Youth could choose a series of mini action projects or one in-depth action project. Outlined below are key learning and guiding questions for each step.

The action steps include:

1. Discovering the action project
2. Planning the action project
3. Putting the project into action
4. Sharing and reflecting on the action project

Facilitator Tip
After completing Step 1, guide your group in choosing a learning approach to plan and carry-out their project. It will be helpful to review the Change Agent Approach Matrix (see Front Matter) prior to guiding your group through the action project steps.

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WAYS TO APPROACH THE ACTION PROJECT

The approach you choose will vary depending on the plastic issue youth want to address. For example, youth may want to study microplastics in the local waterway and collect data to contribute to a scientific study to help inform the public. This action project could use a citizen science approach **or** geo-inquiry approach, depending on the goals of your group. Youth may want to:

- conduct a scientific investigation including data collection and analysis
- embark on an action project to improve a condition in their school or community
- start an advocacy campaign to change a condition or policy

The Change Agent Approach Matrix included in the Front Matter is a guide to help determine the best approach to address the group's question or chosen plastic issue. Here is a brief description of each approach:

- **Citizen science** – an approach where youth collect data which is shared with the professional scientific community to study real-world phenomena.
- **Geo-inquiry** - an approach where youth analyze space, place, and human conditions through maps usually with the aid of geographic information systems (GIS).
- **Community engagement** – an approach where youth get involved in an organized effort on behalf of another government or nonprofit organization to benefit the community.
- **Service learning** – an approach where youth develop a project to benefit others and their community. Service learning can be a direct-service, indirect service, or advocacy-based service project that does not include data collection.
- **Youth participatory action research (YPAR)** – an approach where youth define an issue and research question, conduct an investigation (data collection, analysis), and then take action based on the results. In YPAR, youth develop a project where they collect and analyze data, followed by a service-learning project informed by their data outcomes.

PROCEDURE

Facilitate a group discussion to help youth ask critical questions about our use of plastics. You may choose one or more of the questions below to help guide youth in connecting concept understanding to taking action. Record youth's observations, questions, and discussion on flip chart paper. This discussion will help ground youth in the larger issues as they move into discovering their action project.

- What are some of the concerns about how we use plastics and their impact on our world?
- Describe what happens to plastic after it is used. How do you see your personal role as important or not important in addressing plastic issues? 1
- Imagine you are a lawmaker, what laws or policies about plastics would be beneficial in our community or state?

Lead youth through the key core learning experiences for steps 1-4 using the guiding questions.

Facilitator Tip
Highlight scientists and change agents who are currently working to address real life plastic issues using different approaches. Facilitators can showcase a video from the NSF Center for Sustainable Polymers (https://csp.umn.edu/) or read about innovators transforming the way we use plastics and the way plastics are made. 6 See the Change Agent Approach Matrix including in the Front Matter for examples.

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Girls benefit from collaboration, especially when they can participate and communicate fairly.

6 SciGirls

Interact and learn from diverse STEM role models

Step 1

DISCOVERING THE ACTION PROJECT

Youth generate, discuss, advocate, and select a handful of issues or questions to explore.

The goal is to have students contribute to something larger than themselves and achieve broader impact.

Science and Engineering Practices

Youth engage in asking questions and/or defining problems, a science and engineering practice.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Discovering the Action Project • Youth ask questions and discuss issues related to plastics. • Youth brainstorm/generate ideas for a project/plan to address the issue. • Youth record ideas. • Youth identify what additional information is needed to select a project/plan. • Youth determine ways to address/ solve the issue. 2 • Youth will identify how the project will make a positive change. • Youth select a project.	**Discovering the Action Project** • What do we already know about plastics in our community/world? • What do we wonder about plastic use and the environment? • What information do we need to know about plastics in our community or world (research)? • What critical issue related to plastic use and its environmental impacts do we want to address? • What action can we take to answer or address the question or issue? • How does what we learned about polymers influence how we want to take action?

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Step 2

PLANNING THE ACTION PROJECT

Youth plan and prepare the various steps of the action project in order to be successful.

The goal is for youth to gain project planning skills of organizing tasks, determining resources needed, and creating a project timeline.

Science and Engineering Practices

Scientists and engineers also use this practice of planning their investigation.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Planning the Action Project • Youth discuss and determine project goals. • Youth identify resources. • Youth create action steps/data collection plan to guide the project. • Youth determine who will do what by when.	**Planning the Action Project** • What do we want to achieve in this project? • What skills do we need to accomplish this project? How could we gain them? Who can help? • Who can we invite to partner with us on planning the project? (elected officials/government representatives, businesses, schools or non-profits)? 5 • What steps do we need to take to achieve this goal? • What resources do we need to help us achieve our goal? • What is our timeline - which activities will we do by when? • What are the roles for our group members (who will do what when)? 5 • What else do we need to know to help us be more prepared for this project?

Facilitator Tip
Change Agent Project Planning Tool can be used when developing a detailed project plan (see Front Matter).

Facilitator Tip
During the planning the action project process, youth should identify a range of people in the community that can support their action project. Before reaching out to community members, guide youth as they craft written correspondence, social media posts, and in-person interactions with community members. This will help youth develop and grow their communication skills and gain confidence. Please see the Front Matter for additional resources to support youth in developing their communication skills.

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Step 3

PUTTING THE PLAN INTO ACTION

Youth engage in final project preparation steps and then experience carrying out their action plan.

The goal is for youth to gain confidence through project implementation to effectively serve as change agents and engaged citizens around issues of plastics.

Science and Engineering Practices

Carrying out their planned investigation is a science and engineering practice. 3

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Putting the Plan into Action • Youth implement an action plan. • Youth share project impact/project research. • Youth determine project sustainability.	**Putting the Plan into Action** • What final preparation steps do we need to take in order to implement the plan? • Are there additional people we can invite as we put the plan into action - peers, family members, community members, leaders, others? 5 • How will we record what we did? • How will we share the results of our work? Is it already part of the project (for example, in a citizen science project protocol)?

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Facilitator Tip
Governmental departments, elected officials, and businesses may be eager to support your action project, especially if it aligns well with their mission and goals. They may offer hands-on support of the project (setting up a tour of the local recycling center or a recycling business).

Facilitator Tip
Be sure to take pictures or video during the action project or designate a youth or adult to be the photographer.

Step 4

SHARING AND REFLECTING ON THE ACTION PROJECT

Youth reflect on the action project and share results (e.g., presentations; videos; newsletter/newspaper articles) with peers, community leaders, members of their communities, and other venues.

The goal is for youth to evaluate the project impacts, both on the community and on their own experience.

Science and Engineering Practices

Several science and engineering practices occur in this step, including analyzing and interpreting data, constructing explanations or designing solutions, engaging in argument based on evidence, and communicating information.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Sharing and Reflecting on the Action Project: • Youth analyze and evaluate the project's impact. • Youth reflect on personal learning. • Youth publicly showcase the project. • Youth share results with community and stakeholders. • Youth celebrate project impact and personal contributions.	**Sharing and Reflecting on the Action Project Youth Learning:** • Why did we choose this project? • What was our main goal? What did we accomplish? • What ways did we impact the plastic issue in our community/world? • What could the future of this action/ project look like? • Are there new questions or ideas? • If we were to do this project again, what would we do differently? • Who else can we share our actions/ finding with? • How might we or the community continue elements of the project? • What do you think would happen if more people did this same project?

GUIDING QUESTIONS (CONTINUED)

Youth Leading:

- What did we learn?
- What skills did we gain?
- What was our favorite part of the project?
- What was the hardest part of the project? 3
- How do we feel about what we accomplished in the project?
- How do we feel about how our group worked together during the project?
- What leadership skills did we gain through the project?
- What communication skills did we gain as a result of our project?

Celebrating:

- Who helped us along the way? How should we thank them? 5
- Who else can help elevate and share our actions and findings? How can they help us continue our efforts?
- How can we all celebrate together?

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Facilitator Tip
Use the Change Agent Action Project Evaluation sheet (see Front Matter) to evaluate the outcomes and impact of the action project as well as reflect on personal skills gained through the process. Personal reflection can also include writing, pictures, charts, or other expressions that assess the impact of the project. Create an opportunity for group reflection.

Facilitator Tip
Celebrating provides an opportunity to publicly recognize positive achievements and personal growth of youth. Depending on time available, offer a public showcase of what youth learned and accomplished during the action project. If time is limited, provide certificates of recognition.

CONGRATULATIONS CHANGE AGENTS!

Through the Youth as Change Agents experience, youth addressed the complex issues of plastics in our communities, our country, and our world. Youth gained valuable leadership skills by planning and implementing a plastic focused action project reflective of their interests and passions. They successfully served as important change agents and engaged community members to imagine a new future of plastics. Please be sure to share your action project via #4HSolvetheChallengeofPlastics.

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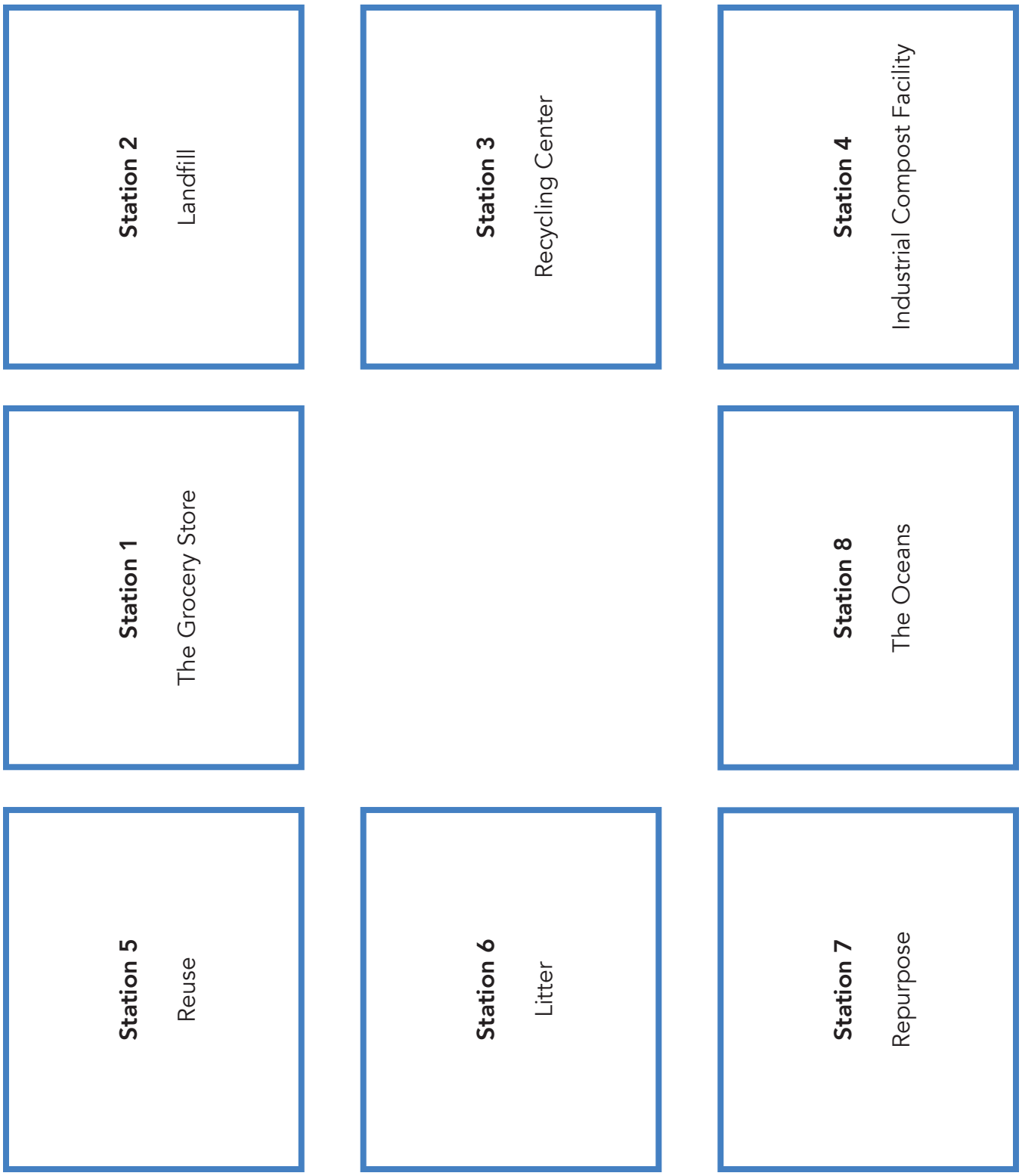
Appendix A

Diagram of Room Set-Up for Learning Stations



Appendix B

Plastic Selection Cards

(Print one-sided and cut apart)

Bioplastic		Petroleum-based Plastic	
Bioplastic		Petroleum-based Plastic	
Bioplastic		Petroleum-based Plastic	
Bioplastic		Petroleum-based Plastic	
Bioplastic		Petroleum-based Plastic	

Appendix C

Station #1: The Grocery Store

You are a plastic water bottle purchased from a grocery store. After you are used by a consumer where will you go? Some consumers will re-use their plastic water bottle. Other disposal options include recycling, littering, composting, and trashing. Each choice has environmental and economic implications.

Roll a die and follow the path according to the number you roll. The consumer decides to:

Roll 1: Recycle their plastic. Go to Station 3.

Roll 2: Place bottle on top of their car. They forget to grab it before they start driving. Go to Station 6.

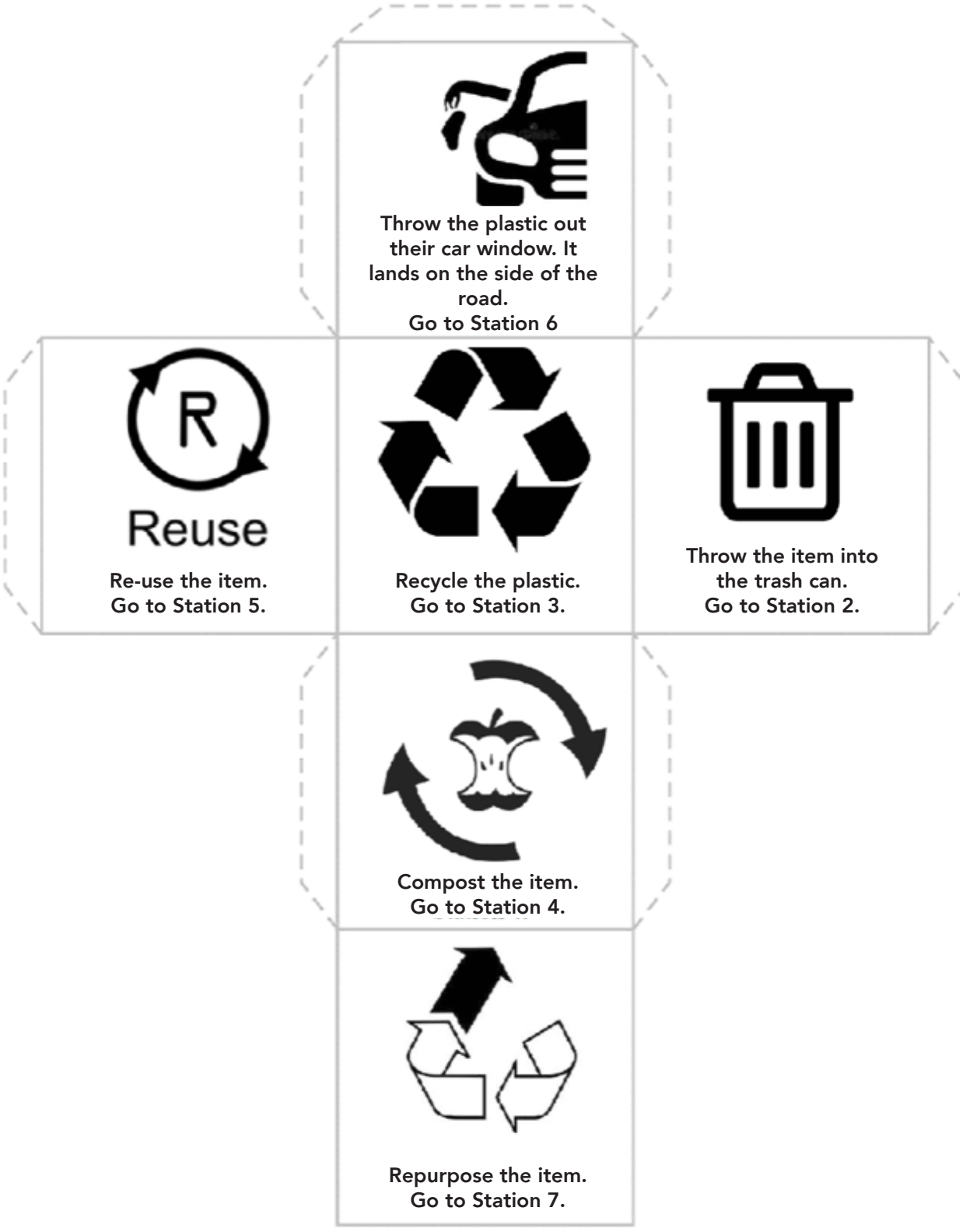
Roll 3: Compost their item. Go to Station 4.

Roll 4: Throw their item into the trash can. Go to Station 2.

Roll 5: Re-use their item. Go to Station 5.

Roll 6: Repurpose their item. Go to Station 7.

Appendix C (Optional)



Appendix D

Station #2: Landfill

Step 1: Pick up the plastic bottles. What do you notice about them? What observations can you make using your sense of sight, smell, touch, and hearing? Use words and pictures to record your observations.

Step 2: Carefully use scissors to cut up the water bottle. How small can you make the pieces?

Step 3: What else do you notice about the plastic? Add any other observations you've made.

Step 4: Based on your observations, describe what you think happens to plastics in a landfill.

After you've made all your observations (your bottle is considered disposed of), go back to Station 1.

Appendix D

Station #2: Landfill

INITIAL OBSERVATIONS	OBSERVATIONS AFTER CUTTING

Appendix E

Station #3: Recycling Center

Find the card that matches your identification (Bioplastic or Petroleum-based plastic), then follow the path according to the card.

Bioplastic: If you're a bioplastic, recycling is not a viable option because you're made from a plant! If some types of bioplastic get recycled it can contaminate other recyclables. Go to **Station 4**.

Petroleum: If you're a petroleum-based plastic, after being recycled, you're made into a new plastic water bottle! Go back to **Station 1** to start life anew.

Appendix F

Station #4: Industrial Compost Facility

Find the card that matches your identification, then follow the path according to the card.

Bioplastic: If you are a bioplastic, you're in the right place! Industrial composts can break down certain bioplastics through decomposition. This decomposition can breakdown the bioplastic entirely and incorporates its nutrients to make soil. Go back to **Station 1** to start life anew.

Petroleum: If you're a petroleum-based plastic, you can't be broken down in an industrial compost. You're shipped to a recycling center. Go to **Station 3**.

Appendix G

Station #5: Reuse

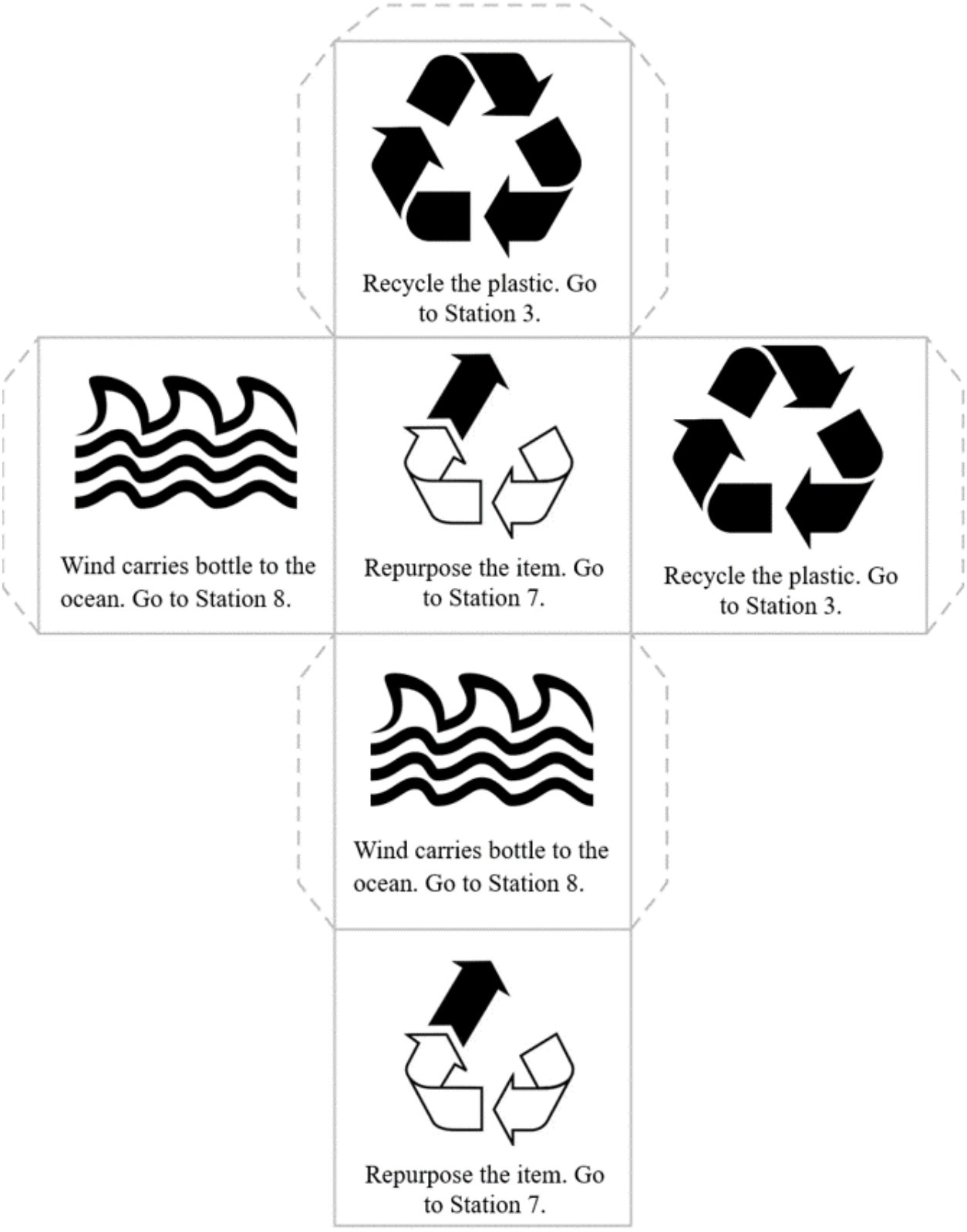
Plastic bottles are intended for one time use. One way to extend the water bottle's life is to reuse it. Roll the die to see what action the bottle takes now.

Roll 1 or 2: After washing the bottle with hot soapy water, the consumer re-uses the bottle for a week. The consumer notices small cracks in the plastic in addition to the bottle smelling stinky. They now place it in the recycling bin. Proceed to Station 3.

Roll 3 or 4: A person re-uses the water bottle for about a week. On a nice summer day at the beach, they accidentally leave the bottle behind. The wind carries the bottle into the ocean. Proceed to Station 8.

Roll 5 or 6: After re-using the water bottle twice, the consumer decides they want to repurpose the item. Proceed to Station 7.

Appendix G (Optional)



Appendix H

Station #6: Litter

These pieces of litter describe various scenarios. Pick one at random and proceed to the instructed station.

Card 1: Wind blows the water bottle pushing it down a sewage drain. It moves through rivers and waterways and into the ocean. Eventually, this bottle makes its way to the ocean. Go to **Station** 8.

Card 2: A grandmother and her granddaughter are on a walk. The granddaughter notices the plastic in the street. After waiting for traffic to clear, the grandmother goes to pick up the plastic bottle. They take it home and decide to make some art. Go to **Station 7**.

Card 3: The city cleaning crew picks up the water bottle and takes it to the city recycling plant. **Go to Station 3.**

Card 4: A person finishes drinking water from a single use bottle and then saves it to use again. Go to **Station 5.**

Appendix I

Station #7: Repurpose

Plastic bottles are intended to be used only once. But you're a plastic bottle of intrigue and mystery; you're going to be repurposed! In your group use the materials provided to sketch, draw, or write a detailed explanation of how a plastic bottle could be repurposed. Some ideas could include: a bird feeder, a pencil holder, or a musical instrument. After finishing at this station, go back to **Station 1**.

Repurpose Idea Name:

Repurpose sketch, drawing, or description:

Repurpose Idea Name:

Repurpose sketch, drawing, or description:

Appendix J

Station #8: The Oceans

According to scientists, 8 million metric tons of plastic went into the oceans in 2010. Plastic can be harmful to ocean life including sea turtles, sea lions, fish, dolphins, and whales. In your groups discuss what role, if any, humans play in plastic getting into the oceans. How could you change the way plastic is disposed? Use the following cards to show how you can stop plastic pollution. After finishing at this station, go back to **Station 1**.

Appendix J

Station #8: Plastic Pledges

Initial next to the action you pledge to take to stop plastic pollution.
Share ideas for following through.

	Refuse	Describe how you will follow through with your pledge:
	Reduce	Describe how you will follow through with your pledge:
	Reuse	Describe how you will follow through with your pledge:
	Recycle	Describe how you will follow through with your pledge:

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

NATIONAL
PEER REVIEWED

MODULE
3
GRADES 6-8

Sustainable Polymers

Taking Action to Solve the Challenge of Plastics

A 4-H STEM Curriculum for Grades 6-8

National Science Foundation

NSF Center for Sustainable Polymers

4-H Polymer Science Curriculum for

Grades 6-8

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 note where the science and engineering practices are used. 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

Facilitator Tips

These tips provide strategies and helpful suggestions for facilitators.

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 3

The Plastic Future: Search for Alternatives and Renewables

Driving Questions:

- **Plastics are useful for everyday life yet are mostly made from non-renewable resources and cause environmental problems. What could a future look like where plastics are sustainable, non-harmful to the environment, and recycled to create energy? How can we each play an important role in achieving this vision?**

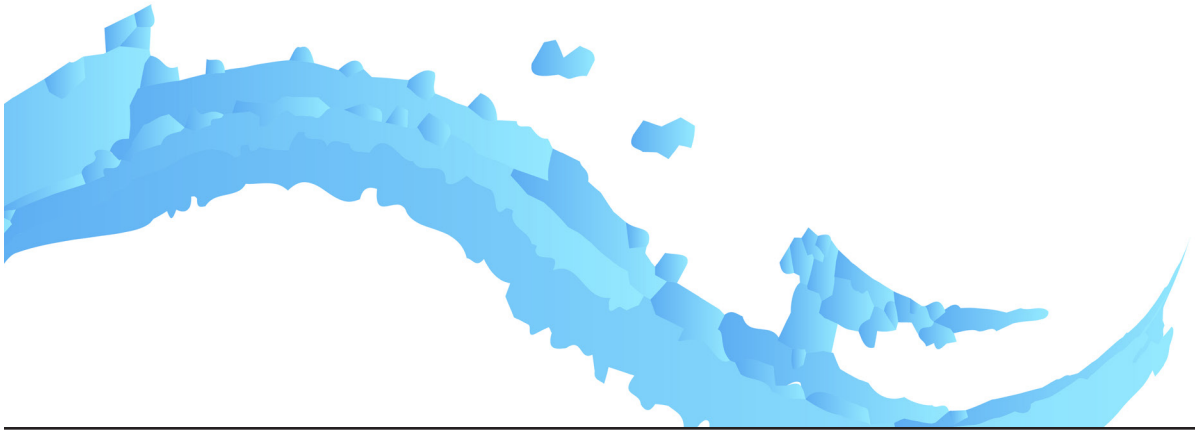
Introduction

MODULE SUMMARY

Using a simulation game, youth "create" traditional plastics or bioplastics and weigh disposal options. As resources are depleted or replenished, youth discover strategies for how to sustain the creation of their plastics when the supply of materials is variable. Youth are also challenged to create a sustainable polymer container that can hold a liquid, explore future uses for this type of polymer as they identify and test variables. Finally, youth will apply their understanding of the complex issue of plastics to imagine an improved future as they plan, conduct, and share a youth-driven action project in their community.

Time Required: 2+ meetings depending on youth-driven action project

- Set up for activity: 10-15 minutes
- Polymer Science Inquiry Activity A: Buy, Sell, Create (30-55 minutes)
- Polymer Science Inquiry Activity B: Create HydroPods! (85-115 minutes)
- Youth as Change Agents Activity: Youth-driven projects (varies, 60-120 minutes)



Module Focus

LEARNING OBJECTIVES	• Youth will understand that while most plastics are made from petroleum/oil, some plastics are made from plant materials (bioplastics). • Youth will analyze the advantages and disadvantages of using renewable and non-renewable materials in the making of polymers. • Youth will plan and implement an action project, and evaluate and communicate the impact to others.
SCIENCE & ENGINEERING PRACTICES (NGSS) 2	• Developing and using models. • Engaging in argument from evidence. • Planning and carrying out investigations. • Obtaining, evaluating, and communicating information.
CONCEPTS & VOCABULARY	• **Bioplastic**: polymers often made from starch-containing plants, such as corn and potatoes. Many of these bioplastics are compostable. • **Change agent**: youth leaders who transform their ideas into actionable projects to create positive social impact. • **Non-renewable resource**: resources that are only available in limited quantities and take a long time to be replenished (i.e. millions of years).

2 SciGirls

Support as they investigate using STEM practices

Module Focus (Continued)

CONCEPTS & VOCABULARY

- **Plastic**: a type of material made from polymers that can be molded into solid objects. Usually made from petroleum/oil.
- **Polymers**: chemical compounds formed from long repeating chains of smaller molecules.
- **Renewable resource**: resources that can be replenished, often within one person's lifetime.
- **Sustainable**: able to be maintained or run continuously with little to no negative impact on the environment or health.
- **Sustainable polymer**: a plastic material that addresses the needs of consumers without damaging our environment, health, and economy.

Facilitator Preparation

MATERIALS NEEDED

BUY, SELL, CREATE

- ☐ Supply cards (at least 5-6 pages of corn/oil and 4 pages of chemical/factory per group)
- ☐ Copies of Appendix A - Playing Cards
  - ☐ Money cards for each group (at least 24 per group) (may use chips/tokens in place of money cards)
  - ☐ Plastic item cards (at least 5-6 per group) (or may use real plastic items)
- ☐ Copies of Appendix B - Recipe Cards and Disposal Options Cards

CREATE HYDROPODS!

- ☐ Electric blender
- ☐ 2 bowls: 1-quart and 2- or 3-quart
- ☐ Cold water
- ☐ Sodium alginate, ¼ tsp for each group of 2-3 youth
- ☐ Calcium lactate; 1 tsp for each group of 2-3 youth.
- ☐ ¼ tsp measuring spoon
- ☐ 1 tsp measuring spoons, 1 per group
- ☐ Large spoons for mixing, 1 per group
- ☐ Other round spoons,such as Tablespoon measuring spoon, round melon-ball scoop, ice cream scoop

GETTING READY

- Practice this game yourself before implementing with youth, so that you have experience with how it works.
- Make copies of money, supply, and plastic item cards (Appendix A).
- Consider how you will divide youth into their groups. This game works best with groups of 2-3.
- Set up a "marketplace" that displays the "recipe" for each plastic type.
  - Print the "recipe" for creating plastics on chart paper or a whiteboard -1 per group (Appendix B).
  - Recipes: Traditional plastics require two oil cards, two chemical cards, and one factory card to create.

    Bio-based plastics require three plant cards, two chemical cards, and one factory card to create.
- Set up a "Scrapyard/ Disposal" where youth can sell or recycle their plastics.
- Designate a helper to assist as you guide this activity (adult or an older youth).

Facilitator Preparation (Continued)

- ☐ Paper towels
- ☐ Food coloring
- ☐ Safety goggles
- ☐ Access to sink with soap to wash hands
- ☐ Bleach wipes or spray to sanitize work surfaces

CREATE HYDROPODS!

- The sodium alginate and calcium lactate can be found at natural food stores or online at Amazon.
- Adults should supervise the use of the blender.
- Wash hands thoroughly before and after this activity.

YOUTH AS CHANGE AGENTS

- ☐ Flip chart paper
- ☐ Markers
- ☐ Copy of Change Agent Approach Matrix - see Front Matter Facilitation Tools

YOUTH AS CHANGE AGENTS

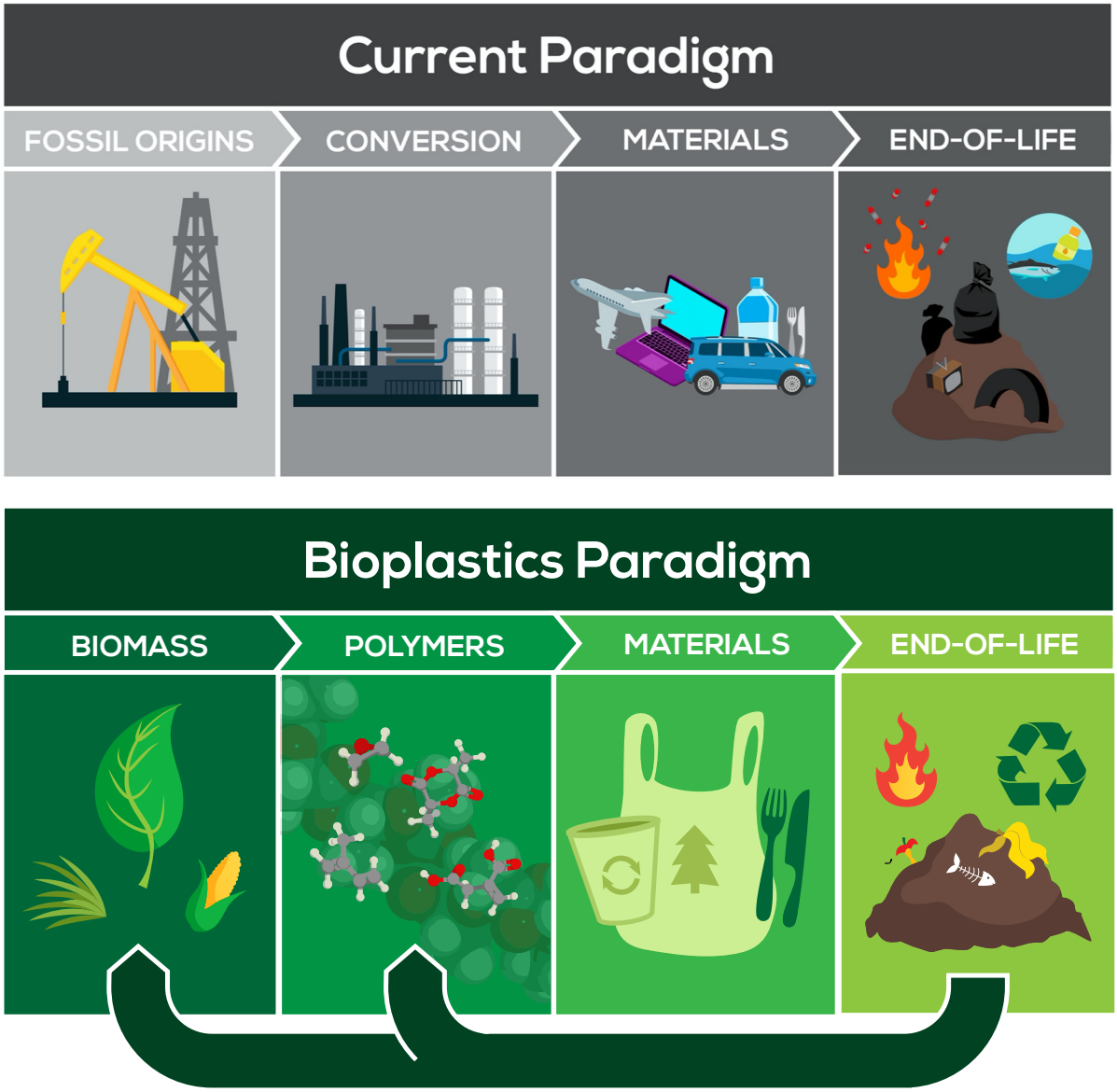
- Review Change Agent Approach Matrix in Front Matter Facilitation Tools.
- For tips on supporting open discussion and collective decision making, see Front Matter Facilitation Tools for active group facilitation strategies.

Background Information for the Facilitator

We have a deep dependence on plastics - from grocery bags and water bottles to high-tech medical devices and computers. **Plastics** make our lives easier because they are durable, lightweight, and easy to produce. The majority of plastics consumed each day are created from petroleum (also known as oil), a **non-renewable resource**. Of all the plastic used for packaging, only 14% is collected for recycling. Most plastic finds its way to landfills as garbage. Out in the environment, oil-based plastics create many environmental challenges because they do not biodegrade. Instead, they break down over time into smaller pieces of plastics. Microplastics are plastics less than 5 millimeters (the size of a pencil eraser top) in length and have been found in many of our rivers, lakes, and oceans, as well as some drinking water.

Many scientists, engineers, non-profits, and even young people are imagining a world where plastics are sustainable, non-harmful to the environment, and recycled to create energy. This big idea is driving the NSF Center for Sustainable Polymers (csp.umn.edu) to develop **sustainable polymers**, **bioplastics**, or plastics made from **renewable resources**. These new bioplastics aim to address the environmental challenges that are inherently associated with traditional (petroleum-based) plastics, yet serve the same purpose as current plastics while remaining cost-effective to produce. Sustainable polymers can be durable and degradable, used in applications from adhesives to packaging to building materials, and produced efficiently and economically with low environmental impact. The most common bioplastic in today's market is **polylactic acid** (referred to as PLA), which is made from corn. PLA is a type of bioplastic that is very versatile and can be composted at industrial compost facilities, meaning it will break down into soil in the proper environment. Some commonly found bioplastic products are PLA cups, PLA silverware, and PLA garbage bags.

Even with these new advancements in plastic materials, scientists and engineers are still working to create bioplastics that are truly sustainable. Renewable materials aren't automatically better for the environment. We need to examine factors in the creation, processing, transportation, use, and disposal of an item to determine the cost/benefits of using such a material. Despite the challenges related to plastics, scientists are committed to developing solutions.



The Youth as Change Agents section of this module is designed to engage youth in transforming plastic impact ideas into actionable projects. Youth will work together to ask critical questions about our use of plastics based on their polymer science learning and discussions. Using an inquiry-based learning approach that best fits your program, youth will:

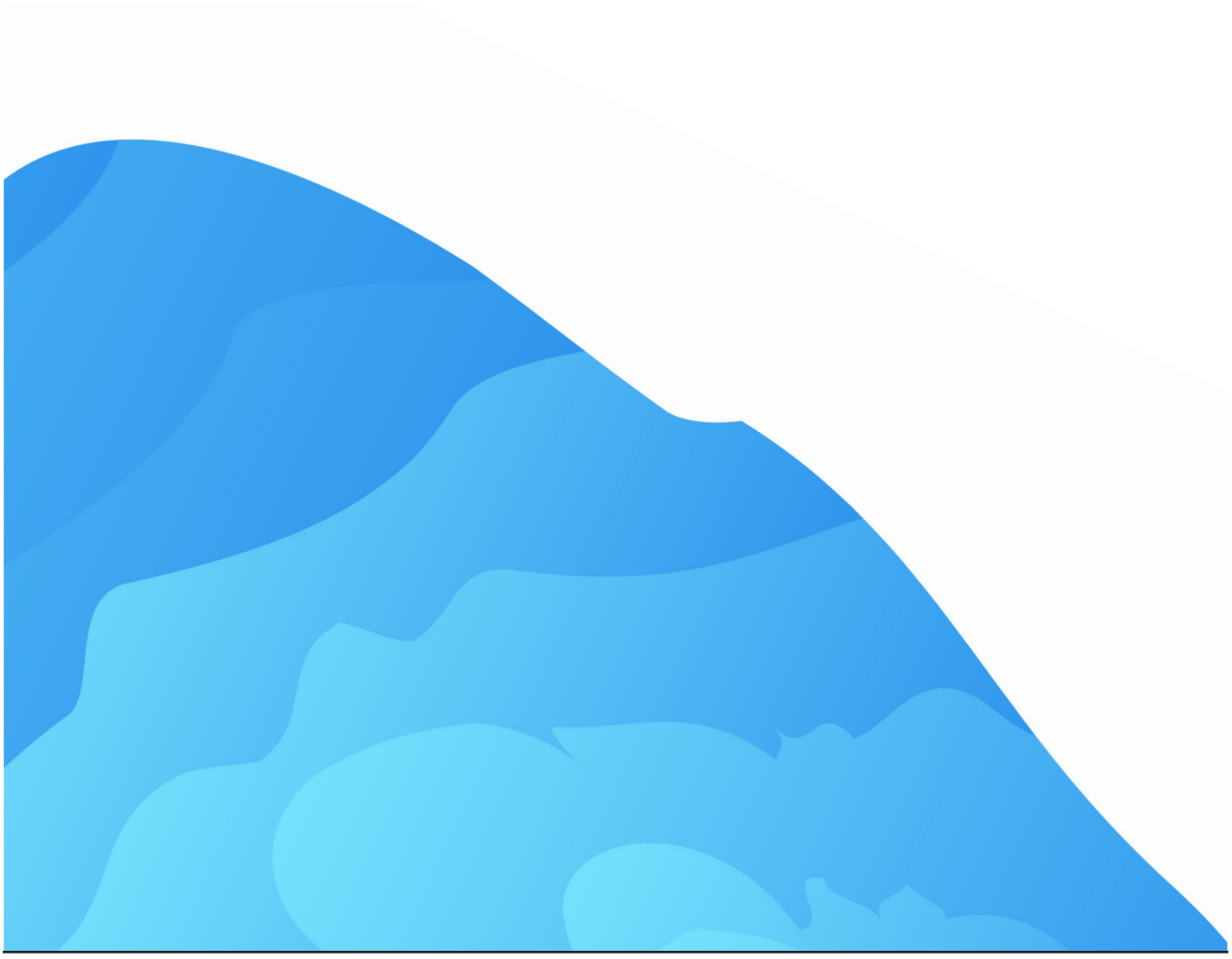
- Develop and implement an action project focused on a specific plastic issue.
- Gain knowledge, skills, and confidence to effectively serve as change agents around plastic related issues.
- Learn from other change agents, both youth and adults, who are working to solve the environmental challenges of plastics.

Polymer Science Inquiry

In this section of the module, youth will explore polymer science content through a guided inquiry activity. Each activity:

- Addresses issues in sustainability and the impacts of plastics.
- Engages youth in science and engineering practices.

If time and interest allow, facilitators can select additional polymer science exploration activities from the Polymer Science Exploration Grid located in the Front Matter Facilitation Tools.



Activity A

Buy, Sell, Create

Youth trade money cards to obtain the resources required to make a plastic. As resources are either depleted or replenished, youth will discover how the availability of resources can influence the types of products that can be created.

FACILITATOR OPENING QUESTIONS/PROMPTS (5-10 MINUTES)

- If we continue to use plastics as we currently do, what does the future look like? (What happens to the plastic, what happens to our environment, and what happens to our communities/world?)

Facilitator Tip
Youth may focus on a world overwhelmed by the negative impacts of plastics. This may cause stress and emotional burdens for youth grappling with the future of the environment. Facilitators should be ready to support youth as they work through the emotional aspect of this forecasting and then shift the tone to more positive possibilities in the next question.

- If we transform how plastics are made and how we use plastics, what does our future look like? (What happens to the plastic, what happens to our environment, and what happens to our communities/world?)

PROCEDURE (EXPERIENCING) (15-30 MINUTES)

1. Divide youth into groups of 2-3. 5 Each group will be trying to purchase the supplies needed to create a plastic item.

5 SciGirls

STEM is collaborative, social, and community-oriented

Facilitator Tip
Invite youth to this simulation game in which their goal is to create plastic. Explain that a simulation is similar to a model; it creates a model of a real-life setting in which they will need to make choices. The "recipes" they use will simulate or mimic the materials and resources needed to make plastic.

Science and Engineering Practices
Note that youth are engaging in one of the Science and Engineering Practices: 'Developing and using models.'

2. The goal of the game is to "create" as many plastic items as possible without running out of money (if a group "creates" a plastic item but then recycles it, it still counts as "created"). Designate half of the pairs/small groups to follow the recipe for traditional plastics; the other half will follow the recipe for bioplastics. If there are uneven numbers, assign more groups to the traditional plastics as this type of plastic is more prevalent in consumer goods.

    a. Recipes:

        - Traditional plastics require two oil, two chemical, and one factory cards to build.
        - Bioplastics require three plant, two chemical, and one factory cards to build.
        - Each card (oil, plant, chemical, or factory) requires one money card to purchase.

3. One facilitator should act as the "marketplace". Youth can purchase oil, plants, chemicals, or factories from the marketplace. If there is an additional facilitator or helper present, the second person should act as the "scrapyard/disposal". One facilitator can serve as both the marketplace and the disposal if necessary.
4. Youth will begin with 24 money cards per group. Youth will take turns buying up to three items in each round. It will take at least two rounds before youth will be able to combine their supplies to make a plastic item.
5. During each round, groups can do each of the following things once:

    a. Purchase supplies. (Up to three items in each round.)

    b. Create up to three plastic items by trading in their supply cards. (If accessible, use real items. If you are unable to collect real items, use the cards with pictures of the items.) Oil cards do not return to the marketplace pile and should be kept in a separate pile not available for re-purchase.

    c. Dispose of plastic items and receive money or resources in return.

6. During each round, groups can do each of the following things once:
    a. Youth can trade one traditional plastic item to:
        - sell = receive six money cards
        - recycle = receive one oil card and three money cards
    b. Youth can trade one bioplastic item to:
        - sell = receive six money cards
        - recycle/compost = receive two plant card and three money cards
7. Continue taking turns creating plastic items, disposing of items, and buying new supplies. Eventually the oil cards will deplete and youth will have to make decisions on how to continue playing the game. Oil cards are the only cards that should deplete; facilitators can replenish plant, chemical, and factory cards as necessary. You can run the game for a certain number of rounds or until the youth run out of money.
8. If time allows, repeat the game with youth following the recipe for the other type of plastic (e.g. groups that created traditional plastics should now create bioplastics, and vice versa).

REFLECTION: SHARE, PROCESS, GENERALIZE (10-15 MINUTES)

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. 3

- Describe one science or engineering skill you practiced through playing this game? 2
- Compare and contrast the challenges we face by using plastic made from non-renewable resources.

Science and Engineering Practices
When youth organize data in this way they are using the science and engineering practice of analyzing and interpreting data.

- Compare and contrast the challenges we face by using plastic made from renewable resources.

CONCEPT AND TERM DISCOVERY

As a reminder, at this point, it is important to ensure that the terms **bioplastic**, **non-renewable**, and **renewable** have been discovered by or introduced to the youth. The goal is to have the youth discover terms and concepts on their own, defining and sharing them with their own words. If youth haven't already shown their knowledge of those concepts, revisit these ideas in a guided discussion.

2 SciGirls

Support as they investigate using STEM practices

3 SciGirls

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

Activity B

Create HydroPods!

Youth are challenged to create a sustainable polymer container that can hold liquid. In Part 1, youth will make the pods following a lab procedure designed by scientists at the NSF Center for Sustainable Polymers. In Part 2, youth will identify a variable to change, make a prediction, and test what happens when they change that variable.

Facilitator Tip
Although the HydroPods have ingredients that could be consumed if food-grade chemicals are used and food safety rules are followed, we do not recommend eating the pods. While these pods are safe to handle, reinforce to youth that other similar looking pods at home (e.g. laundry detergent pods) should not be played with.

Lead a conversation to anchor learning in youth's vision of the future with plastics.

- How could we engineer new solutions that reduce the use of plastic packaging? (Consider one type of single-use plastic and ask yourself: What if we could…?)
- For the solutions we imagined in the previous question, what kinds of experts would we need to help address the problems facing our world? What sounds exciting about the roles they play in creating solutions?

Part 1: Guided Activity

Youth will work in groups of 2-4 to make a HydroPod. The challenge is to create a sustainable polymer container that can hold a liquid. Youth will follow a guided lab procedure.

1. Follow safety rules.
    a. Wash hands with soap and water before the activity.
    b. Clean/sanitize the work surfaces.
    c. Clean the inside and outside of all appliances (blender) and utensils.
    d. Thoroughly wash hands after this activity.

2. Measure 1 cup of cold water and place it into the blender.
3. Add 1 to 2 drops of food coloring.
4. Add ¼ tsp of sodium alginate into the blender and mix for 20 seconds.
5. Pour this mixture into the smaller (1-quart) bowl.
6. In the larger (2- or 3-quart) bowl, mix together 4 cups of cold water with 1 tsp of calcium lactate. Stir with the large spoon until the calcium lactate is dissolved.
7. Fill a 1 tsp measuring spoon with the sodium alginate mixture from the smaller (1-quart) bowl and carefully lower it into the calcium lactate bowl so that the solution covers the spoon.
8. Let the spoon of sodium alginate sit in the calcium lactate solution for about 5 seconds and then slowly turn the spoon over so the pod slides into the calcium lactate solution. Pull the spoon straight up out of the bowl. The alginate pod should now be floating in the solution. (If the reaction does not work well, and a "pod" does not form, remove the teaspoon, and stir in an additional 1/8 tsp of sodium alginate to the smaller bowl with the alginate mixture, then repeat steps 7 & 8).
9. Repeat as desired to make more pods.
10. Let the pods sit for 15-20 minutes. If time is an issue, use a smaller measuring spoon as smaller pods will form faster.
11. Using the large mixing spoon, carefully remove the pods from the solution and set them on a paper towel.
12. Using your senses, observe the pods. To ensure safety, do not use your sense of taste. The pods can be opened to observe the properties of the pods. Share your observations with the group.

Part 2: Science Inquiry

Youth will be challenged to modify their HydroPod. It must hold the liquid yet be easily opened. The container must fit in your hand. Youth should make a prediction and then test what happens when they change one variable.

PROCEDURE (EXPERIENCING) (35-45 MINUTES)

1. Ask groups to talk about the variables involved with making the pods, including ingredients and steps. After individual groups have had time to write these down, have every group share. The facilitator should document these on a whiteboard or flipchart.

Science and Engineering Practices
Note that this is the science and engineering practice of obtaining, evaluating, and communicating information.

2. Ask your group to brainstorm what variables could be changed.

Introduce the I Wonder Board to the group
Use an "I Wonder" process to aid the discussion. For example, "I wonder...what would happen if we used a different liquid?"

Facilitator Tip
The most common variables youth may suggest changing are using a different type of liquid or changing the size or shape of the spoon. Other ideas may also be raised; help youth explore these options as they plan their investigation.

3. Ask each group to decide on one variable they would like to change. Have each group make a new pod following their plan.
4. If time is short, have the class decide on one or two variables to change and do the test together.
5. Analyze your results. Interpret what you observed in each of your experiments. Share relevant data and observations with the other small groups. As a full group, what conclusions can you draw?

REFLECTION: SHARE, PROCESS, GENERALIZE (10-15 MINUTES)

Help guide youth as they question, share, and compare their observations. 2 Choose one or more 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. 3

- Describe a challenge you had as you changed a variable with your pod? How did you address this challenge in your group?
- Describe one science or engineering skill you practiced through creating the HydroPods?
- Describe one way your investigation may be similar to what scientists and engineers are doing to create a future where plastics are sustainable and don't harm the environment. 4

CONCEPT AND TERM DISCOVERY

As a reminder, at this point, it is important to ensure that the terms **sustainable**, **sustainable polymers**, and **renewable** have been discovered by or introduced to the youth. The goal is to have the youth discover terms and concepts on their own, defining and sharing them with their own words. If youth haven't already shown their knowledge of those concepts, revisit these ideas in a guided discussion.

2 SciGirls

Support as they investigate using STEM practices

3 SciGirls

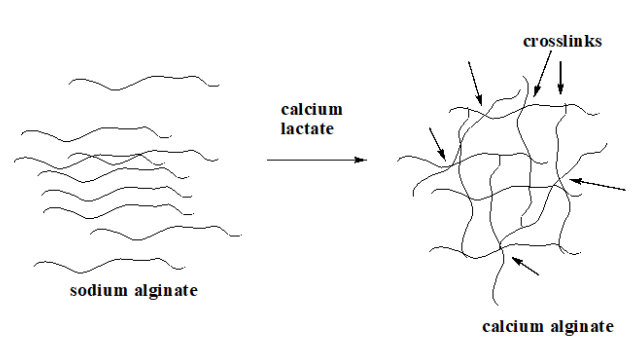
Embrace struggle, overcome challenges, and increase self-confidence in STEM

4 SciGirls

Identify and challenge STEM stereotypes

Facilitator Tip
The pods from this activity are similar to a real, edible water pod, called Ooho!, developed by the company **Skipping Rocks Labs**. Skipping Rocks Labs makes bioplastics from seaweed and plants.

Ooho! is one recent design for replacing plastic water bottles. Oohos! were used during the 2019 London Marathon, preventing the need for 200,000 plastic water bottles. Users could either pop the pod in their mouth and eat it, or drink the water and throw the pod into a compost bin where it will degrade in only six weeks. Skipping Rocks Labs also makes packets for sauces, juices, and condiments that can be composted with food waste. Learn more at: https://www.notpla.com/



Source: https://www.nomaco.com/wp-content/uploads/2019/03/ooho-840x608.jpg

THE CHEMISTRY BEHIND HYDROPODS

In this activity, youth created a HydroPod, a sustainable polymer container that can hold liquid. What's the science around this reaction?

The **sodium alginate** in this experiment comes from algae and is commonly used as a thickener for salad dressings and other liquids. The **calcium lactate** comes from plant sugars and is used as a source of calcium or preservative.

Sodium alginate is a polymer, which means it is made up of long chains of repeating units. When the sodium alginate is placed in the calcium lactate a reaction occurs where the calcium and sodium switch places. In the new calcium alginate polymer chains begin attaching to each other, linking the strands like a chain link fence. This is called cross-linking.

The connected strands form the jelly-like outside of the pod (or capsule) with water trapped inside the pod. The pods are squishy because of the liquid inside.

Part 3: Application in the Real World (10-15 minutes)

1. Ask each group to imagine a different use for biodegradable pods that would address issues of plastic waste and sustainability. Use the following prompts:
    a. Imagine if you could create a larger or smaller pod. What might it be used for?
    b. Imagine a location or situation where this pod would be most useful.
    c. What might be the benefits and disadvantages of this pod? Explain how this might be a sustainable solution.
    d. If useful, draw a picture or model of this pod to share with your group.
2. Invite small groups to share what they have imagined and created.

Youth as Change Agents

In this portion of the module, youth will turn their polymer science learning and plastic impact ideas into an actionable project. Youth will plan and implement an action project that reflects their questions related to plastics. Through this process, youth will gain knowledge, skills, and confidence to effectively serve as change agents around a plastic related issue. 2 3

Background Information for the Facilitator

Facilitators will guide youth through the process of developing an action project. Youth could choose a series of mini action projects or one in-depth action project. Outlined below are key learning and guiding questions for each step.

The action steps include:

1. Discovering the action project
2. Planning the action project
3. Putting the project into action
4. Sharing and reflecting on the action project

Facilitator Tip
After completing Step 1, guide your group in choosing a learning approach to plan and carry-out their project. It will be helpful to review the Change Agent Approach Matrix (see Front Matter) prior to guiding your group through the action project steps.

2 SciGirls

Support as they investigate using STEM practices

3 SciGirls

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

WAYS TO APPROACH THE ACTION PROJECT

The approach you choose will vary depending on the plastic issue youth want to address. For example, youth may want to study microplastics in a local waterway and collect data to contribute to a scientific study to help inform the public. This action project could use a citizen science approach **or** geo-inquiry approach, depending on the goals of your group. Youth may want to:

- Conduct a scientific investigation including data collection and analysis.
- Embark on an action project to improve a condition in their school or community.
- Start an advocacy campaign to change a condition or policy.

The Change Agent Approach Matrix included in the Front Matter is a guide to help determine the best approach to address the group's question or chosen plastic issue. Here is a brief description of each approach:

- **Citizen/Community Science** – an approach where youth collect data which is shared with the professional scientific community to study real-world phenomena.
- **Geo-inquiry** - an approach where youth analyze space, place, and human conditions through maps usually with the aid of geographic information systems (GIS).
- **Community engagement** – an approach where youth get involved in an organized effort on behalf of another government or nonprofit organization to benefit the community.
- **Service learning** – an approach where youth develop a project to benefit others and their community. Service learning can be a direct-service, indirect service, or advocacy-based service project that does not include data collection.
- **Youth participatory action research (YPAR)** – an approach where youth define an issue and research question, conduct an investigation (data collection, analysis), and then take action based on the results. In YPAR, youth develop a project where they collect and analyze data, followed by a service-learning project informed by their data outcomes.

PROCEDURE

Facilitate a group discussion to help youth ask critical questions about our use of plastics. You may choose one or more of the questions below to help guide youth in connecting concept understanding to taking action. Record youth's observations, questions, and discussion on flip chart paper. This discussion will help ground youth in the larger issues as they move into discovering their action project.

- What do we personally care about regarding our world's use of plastics and their impact?
- Describe the pros and cons of using plastic products made from renewable resources. Defend your viewpoint by stating evidence or reasons. 1
- Imagine a future where you are a scientist or engineer with the goal to make plastics non-harmful to the environment. What might you do? 4

Science and Engineering Practices
Note that this is the science and engineering practice of engaging in argument based on evidence.

Lead youth through the key core learning experiences for steps 1-4 using the guiding questions.

1 SciGirls
Connect STEM experiences to lives

4 SciGirls
Identify and challenge STEM stereotypes

Step 1

DISCOVERING THE ACTION PROJECT

Youth generate, discuss, advocate, and select a handful of issues or questions to explore.

The goal is to have students contribute to something larger than themselves and achieve broader impact.

Science and Engineering Practices

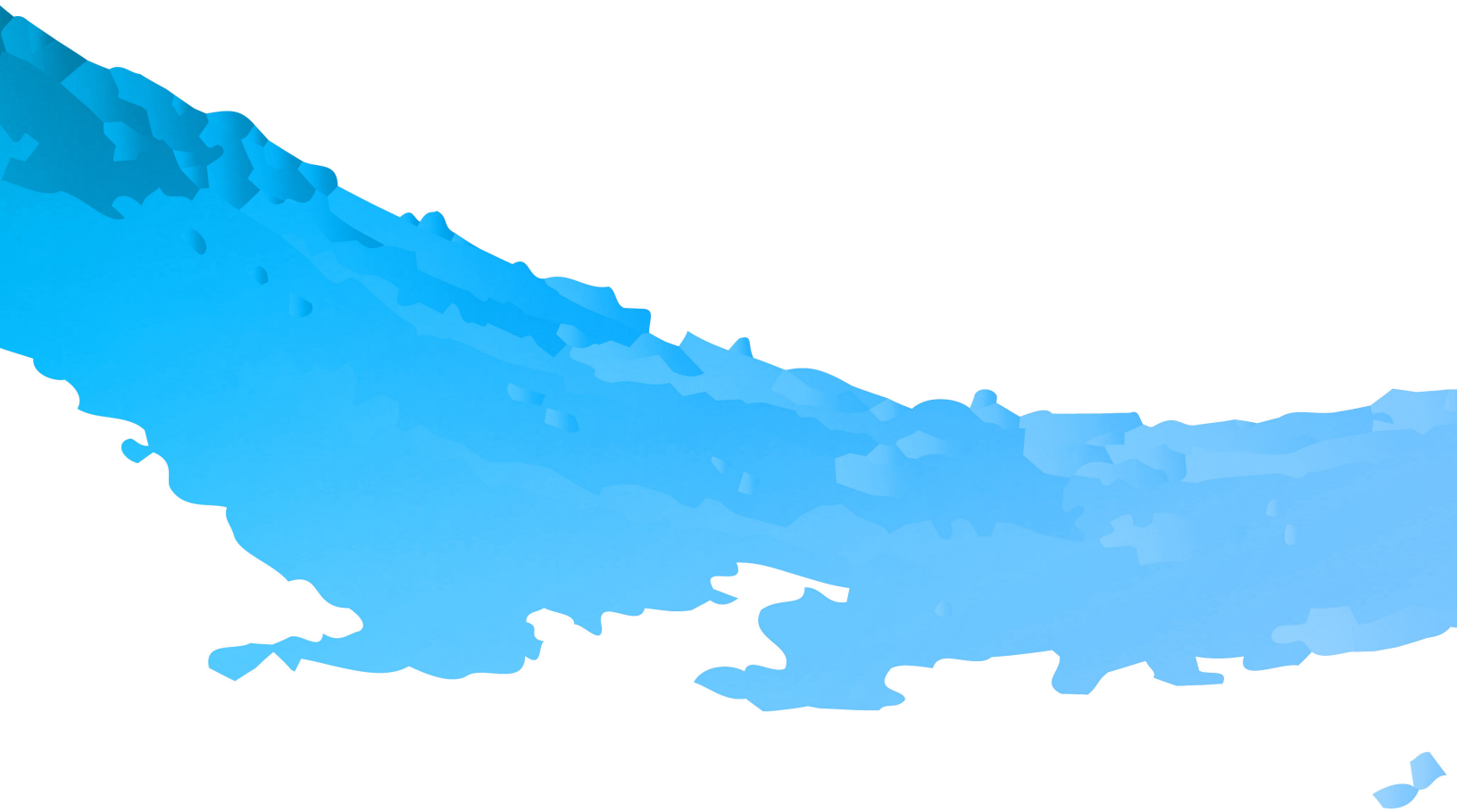
Youth engage in asking questions and/or defining problems, a science and engineering practice.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Discovering the Action Project • Youth ask questions and discuss issues related to plastics. • Youth brainstorm/generate ideas for a project/plan to address the issue. • Youth record ideas. • Youth identify what additional information is needed to select a project/plan. • Youth determine ways to address/ solve the issue. 2 • Youth will identify how the project will make a positive change. • Youth select a project.	**Discovering the Action Project** • What do we already know about plastics in our community/world? • What do we wonder about plastic use and the environment? • What information do we need to know about plastics in our community or world (research)? • What critical issue related to plastic use and its environmental impacts do we want to address? • What action can we take to answer or address the question or issue? • How does what we learned about polymers influence how we want to take action?

2 SciGirls

Support as they investigate using STEM practices

Facilitator Tip
Highlight scientists and change agents who are currently working to address real life plastic issues using different approaches. Facilitators can showcase a video from the NSF Center for Sustainable Polymers (https://csp.umn.edu/) or read about innovators transforming the way we use plastics and the way plastics are made. 6 See the Change Agent Approach Matrix NOT including in the Front Matter for examples.



6 SciGirls
Interact and learn from diverse STEM role models

Step 2

PLANNING THE ACTION PROJECT

Youth plan and prepare the various steps of the action project in order to be successful.

The goal is for youth to gain project planning skills of organizing tasks, determining resources needed, and creating a project timeline.

Science and Engineering Practices

Scientists and engineers also use this practice of planning their investigation.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Planning the Action Project • Youth discuss and determine project goals. • Youth identify resources. • Youth create action steps/data collection plan to guide the project. • Youth determine who will do what by when. 5	**Planning the Action Project** • What do we want to achieve in this project? • What skills do we need to accomplish this project? How could we gain them? Who can help? • Who can we invite to partner with us on planning the project? (elected officials/government representatives, businesses, schools or non-profits)? 5 • What steps do we need to take to achieve this goal? • What resources do we need to help us achieve our goal? • What is our timeline - which activities will we do by when? • What are the roles for our group members (who will do what when)? • What else do we need to know to help us be more prepared for this project?

Facilitator Tip
Change Agent Project Planning Tool can be used when developing a detailed project plan (see Front Matter).

Facilitator Tip
During the planning the action project process, youth should identify a range of people in the community that can support their action project. Before reaching out to community members, guide youth as they craft written correspondence, social media posts, and in-person interactions with community members. This will help youth develop and grow their communication skills and gain confidence. Please see the Front Matter for additional resources to support youth in developing their communication skills.

5 SciGirls

STEM is collaborative, social, and community-oriented

Step 3

PUTTING THE PLAN INTO ACTION

Youth engage in final project preparation steps and then experience carrying out their action plan.

The goal is for youth to gain confidence through project implementation to effectively serve as change agents and engaged citizens around issues of plastics.

Science and Engineering Practices

Carrying out their planned investigation is a science and engineering practice.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Putting the Plan into Action • Youth implement an action plan. • Youth share project impact/project research. • Youth determine project sustainability.	**Putting the Plan into Action** • What final preparation steps do we need to take in order to implement the plan? • Are there additional people we can invite as we put the plan into action - peers, family members, community members, leaders, others? • How will we record what we did? • How will we share the results of our work? Is it already part of the project (for example, in a citizen science project protocol)?

Facilitator Tip
Governmental departments, elected officials, and businesses may be eager to support your action project, especially if it aligns well with their mission and goals. They may offer hands-on e.g. support of the project (setting up a tour of the local recycling center or a recycling business).

Facilitator Tip
Get permission/photo release forms to take photos of youth participating in activities. Designate a youth or adult to be the photographer during the action project.

Step 4

SHARING AND REFLECTING ON THE ACTION PROJECT

Youth reflect on the action project and share results (e.g., presentations; videos; newsletter/newspaper articles) with peers, community leaders, members of their communities, and other venues.

The goal is for youth to evaluate the project impacts, both on the community and on their own experience.

Science and Engineering Practices

Several science and engineering practices occur in this step, including analyzing and interpreting data, constructing explanations or designing solutions, engaging in argument based on evidence, and communicating information.

CORE LEARNING EXPERIENCES	GUIDING QUESTIONS
Sharing and Reflecting on the Action Project: • Youth analyze and evaluate the project's impact. • Youth reflect on personal learning. • Youth publicly showcase the project. • Youth share results with community and stakeholders. 5 • Youth celebrate project impact and personal contributions.	**Sharing and Reflecting on the Action Project** **Youth Learning:** • Why did we choose this project? • What did we accomplish? • What ways did we impact the plastic issue in our community/world? • Are there new questions or ideas? • If we were to do this project again, what would we do differently? • How might we or the community continue elements of the project?

5 SciGirls

STEM is collaborative, social, and community-oriented

GUIDING QUESTIONS (CONTINUED)

Youth Leading:

- What did we learn? What skills did we gain?
- What was our favorite part of the project? The hardest part?
- How do we feel about what we accomplished in the project?
- How do we feel about how our group worked together during the project?
- What leadership skills did we gain through the project?

Celebrating:

- Who helped us along the way? How should we thank them?
- Who else can help share our findings? How can they help us continue our efforts?
- How can we all celebrate together?

Facilitator Tip
Use the Change Agent Action Project Evaluation sheet (see Front Matter) to evaluate the outcomes and impact of the action project as well as reflect on personal skills gained through the process. Personal reflection can also include writing, pictures, charts, or other expressions that assess the impact of the project. Create an opportunity for group reflection.

Facilitator Tip
Celebrating provides an opportunity to publicly recognize positive achievements and personal growth of youth. Depending on time available, offer a public showcase of what youth learned and accomplished during the action project. If time is limited, provide certificates of recognition.

CONGRATULATIONS CHANGE AGENTS!

Through the Youth as Change Agents experience, youth addressed the complex issues of plastics in our communities, our country, and our world. Youth gained valuable leadership skills by planning and implementing a plastic focused action project reflective of their interests and passions. They successfully served as important change agents and engaged community members to imagine a new future of plastics. Please be sure to share your action project via #4HSolvetheChallengeofPlastics.

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Appendix A

Playing Cards

1. *Cards are on the following pages*
2. *Some pages are intentionally blank for proper printing*

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

PLANT

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

PLANT

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

PLANT

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

PLANT

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

CHEMICALS

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

CHEMICALS

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CHEMICALS

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SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

FACTORY

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

FACTORY

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FACTORY

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SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

TRADITIONAL PLASTIC

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SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

TRADITIONAL PLASTIC

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SUSTAINABLE POLYMERS:
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SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

TRADITIONAL PLASTIC

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:

TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

BIOPLASTIC

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:

TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

BIOPLASTIC

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SUSTAINABLE POLYMERS:

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BIOPLASTIC

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SUSTAINABLE POLYMERS:

TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

BIOPLASTIC

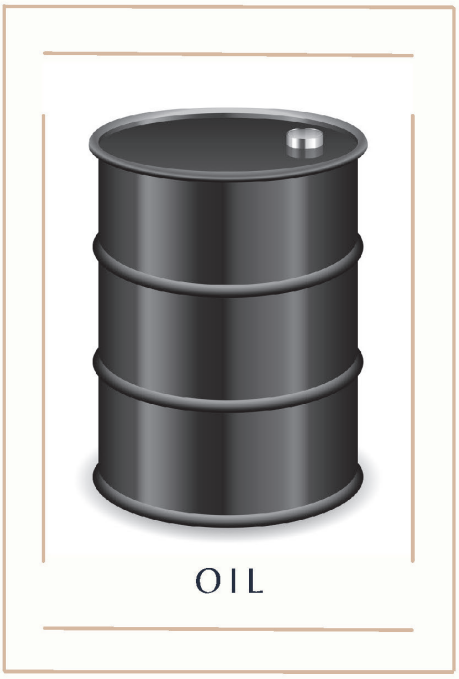
HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

OIL

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS



OIL

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SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

OIL

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SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

OIL

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SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

MONEY

HTTPS://WWW.4HPOLYMERS.ORG/

SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

MONEY

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SUSTAINABLE POLYMERS:
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SUSTAINABLE POLYMERS:
TAKING ACTION TO SOLVE THE CHALLENGE OF PLASTICS

MONEY

HTTPS://WWW.4HPOLYMERS.ORG/

Appendix B

Recipe Card and Disposal Option Cards

DISPOSAL OPTIONS TO EARN MONEY CARD

Traditional plastic items:

- Sell = receive six money cards
- Recycle = receive one oil card and three money cards

Bioplastic items:

- Sell = receive six money cards
- Recycle/compost = receive two plant card and three money cards

DISPOSAL OPTIONS TO EARN MONEY CARD

Traditional plastic items:

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Bioplastic items:

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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