GRADES 9-12

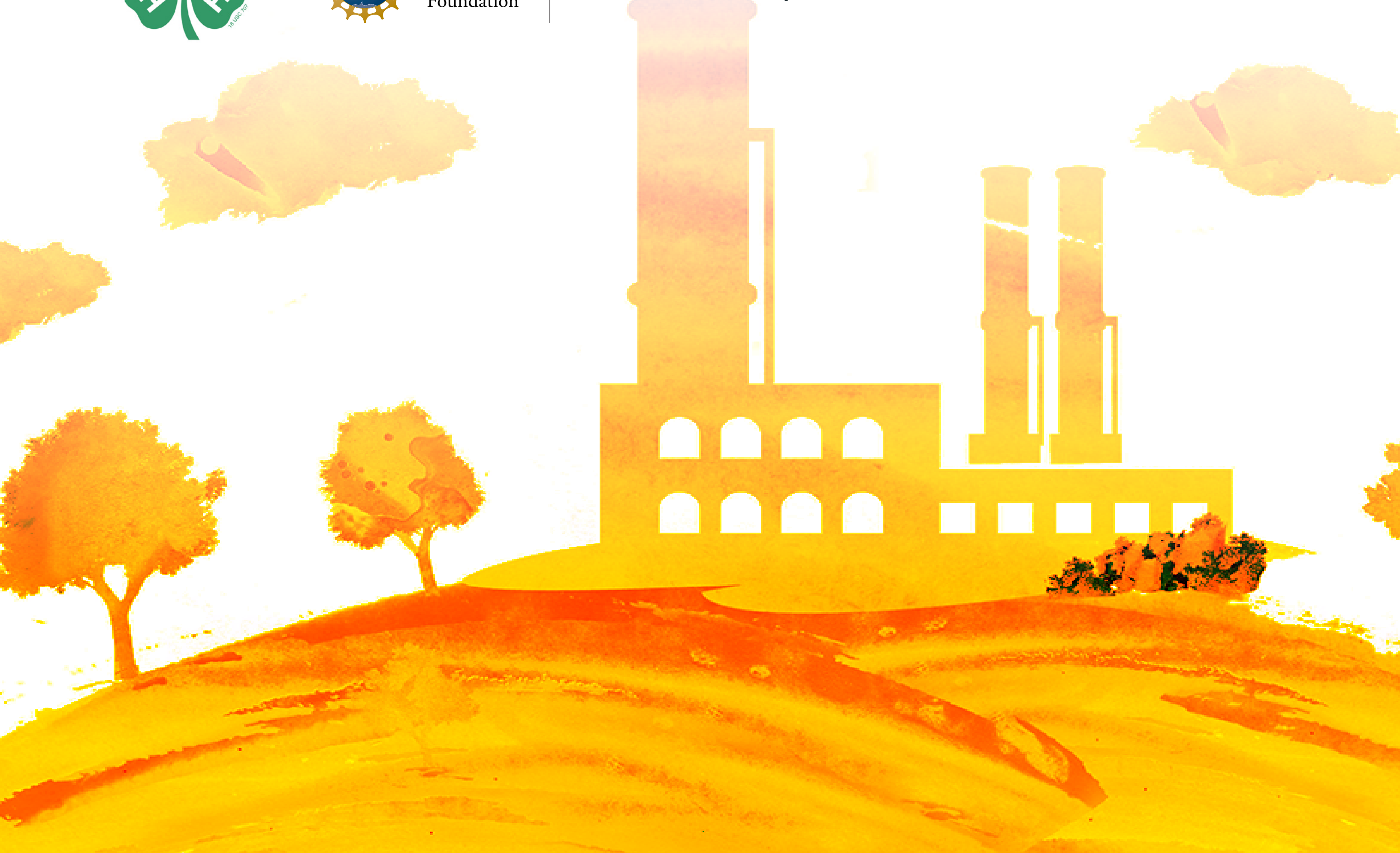
Sustainable Polymers

Confronting the Plastic Crisis

A 4-H STEM Curriculum for Grades 9-12

National Science Foundation

NSF Center for Sustainable Polymers



4-H Polymer Science Curriculum for

Grades 9-12

4hpolymers.org

The curriculum is designed for high school youth focusing on the history, prevalence, impacts, and future of plastics. 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. 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 is intended for delivery in out-of-school time facilitated by an educator (trained volunteers or program staff). Youth will explore polymer science content through a guided activity helping to prepare them for engagement as teachers of younger youth or to undertake a service project. Each module includes educator background reading and additional tips. 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

Front Matter

CURRICULUM TARGET AUDIENCE

Youth in grades 9 to 12 (14- to 18-year-old)

DEVELOPED BY

A partnership between the NSF Center for Sustainable Polymers, University of Minnesota Extension, University of California Agriculture and Natural Resources, Cornell University Cooperative Extension. This work is supported by the National Science Foundation (NSF) under the NSF Center for Sustainable Polymers CHE-1901635.

PROJECT CO-DIRECTORS

- Dr. Jennifer McCambridge, Director of Education, Outreach, and Diversity, NSF Center for Sustainable Polymers
- Anne Stevenson, Extension Educator and Extension Professor, Extension Center for Youth Development – University of Minnesota

AUTHORS

NSF Center for Sustainable Polymers:

- Dr. Jennifer McCambridge

University of California, Division of Agriculture and Natural Resources:

- Emily K. Manroe, Dr. Cheryl Meehan, Dr. Martin Smith, and Dr. Steven Worker

CONTRIBUTORS

University of Minnesota, Extension Center for Youth Development:

- Amie Mondl and Anne Stevenson

Cornell University:

- Alexa Maille, Charles Malone

Layout, Graphics, and Design:

- John Beumer, Senior Graphic Designer, NSF Center for Sustainable Polymers

REVIEWERS

- University of California Cooperative Extension: Nicole Marshall-Wheeler, Jacki Zediker
- University of Minnesota Extension: Michael Compton, Margo Bowerman
- Cornell University Cooperative Extension: Sabrina DeRue, Jessica Reid, Evan Lowenstein, Susan Coyle, Kristina Gabalski
- Pius XI High School (Milwaukee, WI): Patty Hupfer Riedel

INDIVIDUAL MODULE CITATIONS

- Worker, S., & McCambridge, J. (2022). Front Matter. *Sustainable polymers: Confronting the Plastic Crisis. A 4-H STEM curriculum for Grades 9-12*. NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- Manroe, E., Meehan, C., & Smith, M. (2022). Trends in Production and Disposal of Aluminum, Glass, Paper, and Plastic Across Time. *Sustainable polymers: Confronting the Plastic Crisis. A 4-H STEM curriculum for Grades 9-12*. NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- Manroe, E., Meehan, C., & Smith, M. (2022). Comparing the Properties of Aluminum, Glass, Paper, and Plastic. *Sustainable polymers: Confronting the Plastic Crisis. A 4-H STEM curriculum for Grades 9-12*. NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- Manroe, E., Meehan, C., & Smith, M. (2022). Life Cycles of Products We Use and Their Environmental Impacts. *Sustainable polymers: Confronting the Plastic Crisis. A 4-H STEM curriculum for Grades 9-12*. NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- McCambridge, J. (2022). All About Polymers. *Sustainable polymers: Confronting the Plastic Crisis. A 4-H STEM curriculum for Grades 9-12*. NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- Worker, S. (2022). The Plastic Life Cycle. *Sustainable polymers: Confronting the Plastic Crisis. A 4-H STEM curriculum for Grades 9-12*. NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/

- McCambridge, J. (2022). The Plastics Future: Bioplastics. *Sustainable polymers: Confronting the Plastic Crisis. A 4-H STEM curriculum for Grades 9-12*. NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/
- Worker, S. (2022). Emerging Solutions to the Plastic Crisis. *Sustainable polymers: Confronting the Plastic Crisis. A 4-H STEM curriculum for Grades 9-12*. NSF Center for Sustainable Polymers. University of Minnesota. https://www.4hpolymers.org/

LEARNING OBJECTIVES SUMMARY

Modules are based around a ‘driving question’, promoting inquiry into an issue related to plastics. By experiencing all seven modules, youth will explore historical trends and why plastic has become so prevalent, learn about the life cycle of materials and plastics, and start to think about how to mitigate negative environmental impacts of plastic waste. The modules are intended to help improve young people’s knowledge, skills, and awareness such that they can facilitate lessons to younger youth (using the K-2, 3-5, or 6-8 curricula) or undertake their own service project.

MODULE SUMMARIES

1. **Module 1: Trends in Production and Disposal of Aluminum, Glass, Paper, and Plastic Across Time.** *What are the historical trends for the production and disposal of plastics, glass, aluminum and paper products?* Youth will analyze historical (1960s to 2018 U.S.) production and disposal data tables for plastic, glass, aluminum, and paper. By graphing the data, youth raise their awareness of trends in production and disposal of the four materials comparatively. Youth will communicate evidence about an issue informed and inspired by the data to a larger public audience.
2. **Module 2: Comparing the Properties of Aluminum, Glass, Paper, and Plastic.** *Why are specific materials selected for specific use cases? Why have plastics become one of the most utilized materials in the world?* Youth make comparisons and draw inferences about the physical characteristics of plastic, glass, aluminum, and paper through observation of household items. Youth create an inventory and reflect upon the materials present in the items they interact with daily in school and personal contexts. Youth begin to understand that the applications of different materials depend on the advantages and limitations of each material’s properties, characteristics, and abilities.
3. **Module 3: Life Cycles of Products We Use and their Environmental Impacts.** *What are the environmental impacts of common packaging materials – aluminum, glass, and plastic – throughout their life cycle, from extraction of natural resources and product production through consumer use and disposal?* Youth will conduct web-based research on the life cycles of glass, aluminum, and plastic and learn about the environmental impacts associated with each life cycle stage. Specifically, youth will investigate the environmental effects relative to the production of aluminum, glass, and plastic beverage containers from the time natural resources are extracted through to product production, consumer use, and disposal (landfill waste, recycled material, or repurposed product). Youth will then have opportunities to engage in real-world applications of their new knowledge to help address environmental issues associated with material waste in their communities.
4. **Module 4: All About Polymers!** *What is it about plastic that makes it so versatile?* Youth use model polymer chains to explore how structure influences material properties. Youth will also observe biodegradation using a variety of material samples. With these two

activities, youth will understand the same reasons that make plastics a strong material also contribute to their detrimental environmental effects.

The second activity in this module is done over two sessions that require a two week wait in between. Educators can begin another module during the waiting period.

5. **Module 5: The Plastic Life Cycle.** *What happens to all the plastic we continue to consume? What impacts does plastics have on the environment?* Youth simulate becoming a particle of "plastic" and follow it from one learning station to another throughout its material life cycle, being extracted, manufactured, consumed, and disposed. The resin code the plastic is manufactured in to, and chance encounters (dice rolling) determine end-of-life: refuse/landfill (or ocean), recycle, recovery/energy, or reuse.
6. **Module 6: The Plastics Future: Bioplastics.** *How can we develop materials that have the advantages of plastic but fewer of the negative impacts? What are the advantages and disadvantages to transitioning to renewable plastics?* In activity A, Youth will explore the properties of different plastic types to understand the advantages and disadvantages based on application. If the group has access to a microwave, youth will create their own bioplastic sample from cornstarch. If no microwave is available, store bought samples of different plastic cups will be tested to explore how the properties of materials affect its function. In activity B, youth are challenged to create a sustainable polymer container that can hold a liquid and explore future uses for this type of polymer as they identify and test variables. 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 make a change to a variable, make a prediction, and test what happens.
7. **Module 7: Emerging Solutions to the Plastic Crisis.** *What are the advantages and disadvantages in emerging methods to deal with the detrimental impacts of petroleum-based plastic?* Youth prepare and deliver a pitch to a "Shark Tank" panel of investors who listen to pitches for products and decide whether to invest. Youth will prepare a pitch for an emerging technology or other solution to deal with detrimental impacts of plastic. Youth use scientific information, may gather additional information, and include? a life cycle assessment. Youth will reflect as a large group on the advantages and disadvantages of each proposal.

CONTENT SUMMARY

The theme of these modules focuses on the prevalence, life cycle, and impact of plastics in everyday life. Plastics are versatile materials that come in different shapes, sizes, and exhibit different material properties (most commonly referred to by their resin code).

Plastics may 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 is easy to find examples of plastics in everyday life and we all encounter plastic items at multiple points each day. Few other materials, such as paper, aluminum, or glass, are as versatile as plastics. This versatility is perhaps why plastics have surged in production and usage in the last century, making their way into almost every facet of modern life.

Unfortunately, the chemical properties (long polymer chains) that make plastics so strong, durable, and flexible, also make them resist degradation. 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. Plastics may break into smaller and smaller pieces (called microplastics). Microplastics are particularly harmful in aquatic environments because they are easily ingested by animals and can end up in drinking water.

The most effective method to reduce plastic waste is not to create it. Once created, reusing, repurposing, or upcycling a plastic product helps increase its lifespan. Another option in some places is to recycle plastics. 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 made from renewable resources (like corn or potatoes) 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.

Module 1

Trends in Production and Disposal of Aluminum, Glass, Paper, and Plastic Across Time

Driving Questions:

- **What are the historical trends for the production and disposal of plastics, glass, aluminum and paper products?**

Introduction

MODULE SUMMARY

Youth will analyze historical production and disposal data tables (1960s to 2018 U.S.) for plastic, glass, aluminum, and paper. By graphing the data, youth raise their awareness of trends in production and disposal of the four materials comparatively. Youth will communicate evidence about an issue informed and inspired by the data to a larger public audience.

Time Required:

- Set-up for activity: 15 minutes
- Activity: 60 minutes

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.

Module Focus

LEARNING OBJECTIVES	At the conclusion of this activity, youth will be able to… • Understand data tables that display data on a longitudinal (over time) scale. • Convert table data to graphs by correctly plotting data points on the x and y axes. • Interpret graphical data and compare graphs that use different scales. • Make inferences about changes over time including cause and effect. • Integrate graphs into the development of an argument, case study or proposal.
SCIENCE & ENGINEERING PRACTICES (NGSS)	• Analyzing and Interpreting Data • Obtaining, Evaluating, and Communicating Information
CONCEPTS & VOCABULARY	• **Data Table**: a way of displaying multiple categories of information (often numeric). Data are represented in rows and columns. • **Line Graph**: graph that uses a line to connect individual data points that are organized over a specific time interval. • **Longitudinal Data**: collection of repeated observations, or data points, presented over time.

Module Focus (Continued)

CONCEPTS & VOCABULARY

- **Microplastics:** plastic fragments (less than 5mm in diameter - the size of pencil eraser) that are produced for certain products or result from larger plastic products degrading. Microplastics comprise approximately 90% of plastic pollution in the open oceans and are detrimental to marine life.
- **Plastics**: a type of material made from polymers that can be molded into solid objects.
- **Single-use Plastics**: any plastic product that is designed to be used once and then thrown away or recycled. This includes plastic storage bags, grocery bags, food wrappers, disposable drink bottles, plastic food wrap, straws, takeout containers, and disposable partyware.
- **Trend**: relationship between two sets of data. If the values of one set of data increases and the values of other set also increases, then the two sets of related data show a **positive trend**. If the values of one set of data increases and the values of other set decreases, then the two sets of related data show a **negative trend**.
- **X-axis**: horizontal axis of a two-dimensional plot.
- **Y-axis**: vertical axis of a two-dimensional plot.

Facilitator Preparation

SUGGESTED GROUPINGS

- ☐ Pairs or small groups of 3-4

MATERIALS NEEDED

- ☐ Copies of Appendices A-D: Data Tables (one per group; cut along lines)
- ☐ Copies of Appendices E-H: Blank Graphs (one set per group)*
- ☐ Copies of Appendix I: Interpretation Template (one per youth)
- ☐ Ruler or other straight-edge
- ☐ Writing materials: (one set per youth)
  - ☐ Pencils
  - ☐ Coloring utensils*: Red, Blue, and Black markers, crayons, or colored pencils
- ☐ Optional Technology-Supported Procedure: Computers with Microsoft Excel (or Google Sheets). *Coloring utensils not needed for this option.

GETTING READY

- ☐ Divide your youth into pairs or small groups.
- ☐ Decide if you will be using the "Pencil and Paper Procedure" or the "Technology Supported Procedure."
- ☐ Gather supplies and make copies of the Appendices as outlined in "Materials Needed."

Background Information for the Facilitator

Materials, such as aluminum, glass, paper, and plastic are selected for use in commercial goods, household items, and packaging based on their cost and physical properties. Throughout time, these materials have competed in multiple domains for the cheapest and easiest production. Aluminum began to phase out heavier metals in aviation and space travel and made its widespread public debut in 1959 with the beer can. Soon, aluminum beverage cans outperformed and outnumbered glass bottles. Looking at other materials, by 1925, paper bags had phased out the more-expensive cloth bags. Cardboards and cartons also began to take over aluminum and tin packing of crackers, oatmeal, and bandages towards the end of the 1900s. Glass and cardboard cartons have long battled as premier packages for milk and other dairy products; today, you are more likely to find cardboard cartons of milk and cream on the dairy box shelves. High demand for **plastics** began during WWII when the need for cheap, lightweight, and durable equipment for soldiers abroad caused plastics production in the US to quadruple (Science History Institute, n.d.). Since that time, our demands for plastic products have grown rapidly. In fact, plastic production increased by 19,000% between 1950 and 2015 to meet those demands! Overall, even though plastic dominates our modern packaging, products like cardboard and aluminum have begun to phase out other heavier and more costly materials.

Today, plastics are present everywhere in our daily lives. Many of the plastic items we are most familiar with are **single-use plastics**, like food containers, water bottles, wrappers, and grocery bags that are typically discarded after being used only one time. Plastics are also commonly used in durable products such as automobiles, furniture, pipes, insulation, cell phones, televisions, computers, and many other products. In 2015, about 380 million tons of plastic products were produced globally, with about 146 million tons produced only as packaging.

Plastics do not break down quickly or naturally in the environment, and with approximately one-half of all plastic products marketed as single-use items or packaging, effective disposal is an issue. Between 1960 and 1980, plastics' negative effects on wildlife, increased plastic litter, as well as concerns over disposal and a lack of degradability contributed to plastics' declining reputation among the public. To help regain public support, the plastics industry began promoting recycling programs in the 1980s. The classic recycling symbol debuted in 1988, more than ten years after single-use drink bottles and plastic grocery bags hit the market. However, recycling has not been the solution it was advertised to be. In 2018, an average of only 8% of all plastic waste was recycled. It is estimated that 75% of plastic waste is disposed of in landfills, and approximately 10% of plastic refuse ends up in the world's oceans.

In addition to recognizable plastic objects (water bottles, bags, etc.) plastic pollution also includes microplastics. **Microplastics** are tiny plastic particles that are purposely designed for commercial use (such as cosmetics) or are shed from plastic textiles such as fishing nets. Microplastics can also be derived from the breakdown of larger plastic items as they degrade over time. In fact, washing a laundry load of shirts made of plastic-based fabric like polyester can release between 600,000 and 1,000,000 microplastics into the water system! Microplastics are particularly harmful in aquatic environments because they are easily ingested by animals and can end up in drinking water.

Plastic pollution, whether obvious or microscopic, has worsened over time due to the increased demand for, and use of, plastic products coupled with ineffective processes for recycling or safe disposal. In this activity, we will compare trends in consumption and recycling of plastics with other materials such as glass and aluminum and youth will make inferences about the similarities and differences between the use and disposal of these materials.

Activity

OPENING QUESTIONS/PROMPTS

This is where the activity begins. Asking opening questions helps frame the thinking of the youth, as well as provides educators with some understanding of youths' prior knowledge and experience.

- Describe different types of packaging materials used for various goods and possessions we purchase and use in our everyday lives (e.g., food, clothing, bath and laundry products, school supplies).
- Describe your understanding of some of the advantages and/or disadvantages of using these different packaging materials.
- Describe what, if anything, you know about how the production and disposal of packaging materials has changed over the last 50 years.

PROCEDURE

Experience Step; this is the hands-on activity; first step in the learning cycle.

1. Have the groups of youth separate into different areas with a working space such as a desk or table.
2. Provide each group with a set of Data Tables (Appendices A-D; cut to separate). If there are 4 youth per group, each youth should have one of the tables (i.e., glass, plastic, etc.). If there are fewer than 4 youth per group, then some members may receive more than one table. If more than 4 members per group, then youth can partner up within the group.
3. Have the youth review the data tables provided and discuss the data tables within their groups.

Facilitator Tip
If youth need help conceptualizing the magnitude of the weights, remind them that a medium-sized car weighs about 2 tons. Therefore, 20,000 tons would equal the weight of 10,000 cars. Also, the data tables are given in thousands of tons, so remind the youth that "1,000" in the table is actually "1,000 thousand", which is equal to 1 million.

4. Choose one of the following procedures to continue.

Pencil and Paper Procedure:

1. Provide each group with a set of Graph Templates (Appendices E-I), pencils and colored writing utensils. Each colored utensil will represent a data category:
   a. Weight of Total Waste = Red
   b. Weight of Recycled Waste = Blue
   c. Weight of Buried Waste = Black
2. Instruct the youth to create line graphs by transferring the data provided in their table onto the graph template. Each category of data should be plotted and graphed in the corresponding color and a legend should be included on the graph. If the youth are unsure how to do this, provide them with the following hints.
   a. Time (decade) is represented on the X-axis (horizontal)
   b. Weight of Product Waste, Weight of Products Recycled, and Weight of Products Buried are represented on the Y-axis (vertical).
   c. Step 1: Plot all points for one category (Waste, Recycled, Buried)
   d. Step 2: Connect the points with a line.
   e. Repeat this process for all three categories.

Technology-Supported Procedure:

1. Using Excel or Sheets, have the youth create a data table based on the printed table provided. The table should be formatted as presented in the printed version with the same column and row labels.
2. Use "Insert" to select "Line or Area Chart" to generate a graph of the data.
   a. Make sure that the x and y axes are labeled and that there is a legend corresponding to each data category.
3. Format line colors as follows:
   a. Weight of Total Waste = Red
   b. Weight of Recycled Waste = Blue
   c. Weight of Buried Waste = Black
4. If possible, print graphs for ease of comparison and discussion.

Both Options:

1. After all the graphs are completed, hand out the **first page** of the Data Interpretation Template. Have youth complete Part 1 and share their responses within their groups.
2. Ask the youth to compare and contrast their graphs with those of their groupmates and complete the Part 2 of the Data Interpretation Template.
3. Hand out the **second page** of the Data Interpretation Template.
4. Ask the youth to complete Part 3 of the Data Interpretation Template and share their responses within their groups.

REFLECTION: SHARE, PROCESS, GENERALIZE

Share, Process, Generalize (Step two in the learning cycle); youth share their reactions and observations publicly and processes the experience by discussing and analyzing. Help guide youth as they question, share, and compare their observations. 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.

Bring the pairs/small groups together to share their responses on the Data Interpretation Template. Initiate a discussion whereby pairs/small groups share their observations and reactions to their experiences of analyzing and comparing the data. Ask the youth to describe how they went about the process of making sense of the data, and to discuss their interpretations of the outcomes.

Facitator Tip
Look for evidence of understanding relative to graphing, data interpretation using different scales, and cause and effect inferences based on the data. For example, the graph templates have different scales for weight (Y-axis) and this difference is important when comparing across graphs.

If needed, some prompt questions may include:

1. Based on the data, describe trends in disposal of plastics, aluminum, glass, and paper over time.
2. Discuss some potential implications relative to these trends.
3. Explain how creating data tables, understanding data, and interpreting graphs could be relevant to your learning and/or careers.

Science and Engineering Practices
Analyzing and interpreting data

Facilitator Tip
To increase engagement, encourage a discussion about the relevant environmental implications of these disposal trends. Guide the conversation towards their understanding relative to the environmental impacts of waste.

Facilitator Tip
Encourage these links between data comprehension and scholastic pursuits, as well as the relevance they see to being critical media consumers.

CONCEPT AND TERM DISCOVERY

A critical, intermediate step where the goal is always to have the youth develop their understanding using their own words and as a result of the experience; however, if misunderstandings/misconceptions develop, the facilitator needs to address them. Conceptual understanding develops during discussions among youth during the Reflection phase of the activity; technical terms are also frequently used. During these discussions, facilitators need to assess concepts and/or terms the youth have understood through the activity. Any concepts or terms the youth do not discover or understand will need to be introduced by the facilitators before moving to the Application phase.

CONCEPT APPLICATION

Last step in the learning cycle; this links learning to participants' lives through authentic applications to their own practices. The true test of youth' 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 for authentic applications. Suggestions for real-world applications include:

Using their computers, tablets, smartphones, or poster paper/writing materials, ask youth to develop one or two infographics:

Option 1: Design an infographic that helps others understand an issue pertaining to material production and disposal that you think is important.

- Audience: Younger Youth
- Example (For Facilitator Only): See Appendix K and/or Facilitator Tip below

Option 2: Design an infographic that takes a stance on an issue you see in the material production and disposal data.

- Audience: City council or other local government bodies
- Purpose: Suggest policies or ways to educate the community about waste production (and/or decreasing waste production) in an effort to decrease their overall impact on the environment.

Science and Engineering Practices
Analyzing and interpreting data

Facilitator Tip
See the following links for infographic tips and examples.

Centers for Disease Control:
https://www.cdc.gov/socialmedia/tools/InfoGraphics.html

Easelly:
https://www.easel.ly/blog/10-great-examples-of-using-infographics-for-education/

St. Cloud State Univ.:
https://stcloud.lib.minnstate.edu/subjects/guide.php?subject=visualinfo

The University of Queensland:
https://www.clips.edu.au/infographics/

University of Pennsylvania:
https://guides.library.upenn.edu/infographics/creating

REFERENCES

A brief history of plastic. (2020). Lafayette. https://magazine.lafayette.edu/spring2020/2020/03/22/a-brief-history-of-plastic/

Britannica, T. Editors of Encyclopaedia (2019, November 15). *Polyethylene. Encyclopedia Britannica.* https://www.britannica.com/science/polyethylene

Carnegie Mellon University. (2021). *Natural vs synthetic polymers.* https://www.cmu.edu/gelfand/lgc-educational-media/polymers/natural-synthetic-polymers/index.html

Colman, S. (2020, September 10). *A brief history of plastic* [Video]. TED-Ed. https://ed.ted.com/lessons/a-brief-history-of-plastic

De Falco, F., Di Pace, E., Cocca, M., & Avella, M. (2019). The contribution of washing processes of synthetic clothes to microplastic pollution. *Sci Rep*, *9*, 6633. https://doi.org/10.1038/s41598-019-43023-x

Environmental Protection Agency. (2021, July 2). *Aluminum: Material-specific data*. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/aluminum-material-specific-data

Environmental Protection Agency. (2020, November 12). *Glass: Material-specific data*. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/glass-material-specific-data

Environmental Protection Agency. (2020, December 15). *Paper and paperboard: Material-specific data.* https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/paper-and-paperboard-material-specific-data

Environmental Protection Agency. (2021, September 30). *Plastics: Material-specific data.* https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data

Geyer, R., Jambeck, J., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances, 3*(7). 10.1126/sciadv.1700782

Moore, C. (2021, November 17). Plastic pollution. *Encyclopedia Britannica.* https://www.britannica.com/science/plastic-pollution

Plastic life. (n.d.)Plastic Garbage Project. https://www.plasticgarbageproject.org/en/plastic-life

Science matters: The case of plastics. (2021).Science History Institute. https://www.sciencehistory.org/the-history-and-future-of-plastics

Taddonia, P. (2020, March 31). Plastics industry insiders reveal the truth about recycling. *PBS Frontline.* https://www.pbs.org/wgbh/frontline/article/plastics-industry-insiders-reveal-the-truth-about-recycling/

Timeline. (n.d.). The Plastics Collection. https://plastics.syr.edu/page-timeline.php

Trossraelli, L., & Brunella, V. (2003). Polyethylene: discovery and growth. https://www.researchgate.net/publication/228813221_Polyethylene_discovery_and_growth