National Aeronautics and Space Administration

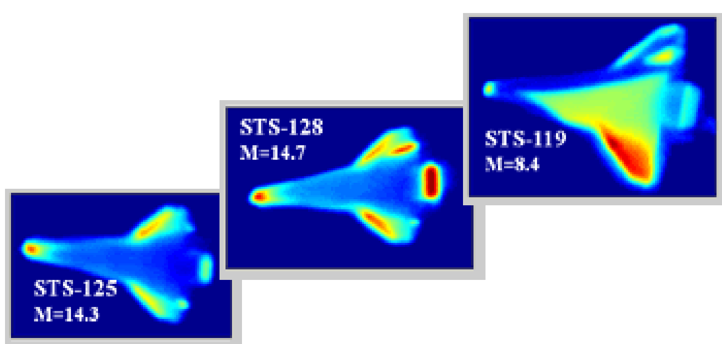
NASA eClips™

Guide Lites

Interactive Lesson

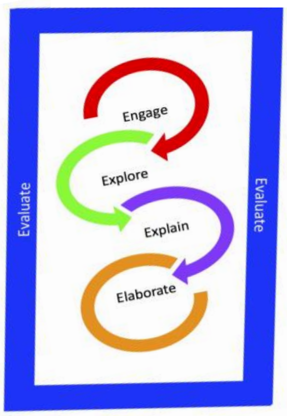
Testing…1, 2, 3…Testing: Nondestructive Evaluation

Grades 8-12



NASA eClips™ Guide Lites are individual supplemental activities that are developed for formal and informal educational settings. Currently there are two types of Guide Lites:
1) excerpts from approved NASA eClips™ Educator Guides; and
2) targeted vocabulary lessons that help students confront science misconceptions addressed within NASA Spotlites, student-produced videos.

NASA eClips Guides use the "Five E" constructivist model developed by Roger Bybee. Constructivism is an educational philosophy that promotes student-centered learning where students build their own understanding of new ideas. The 5E instructional model consists of five sequential stages for teaching and learning: Engage, Explore, Explain, Extend (or Elaborate), and Evaluate.



- The ENGAGE stage piques student interest and gets them personally involved in the lesson, while pre-assessing prior understanding.
- The EXPLORE stage gets students involved in the topic, providing them with the opportunity to build their own understanding.
- The EXPLAIN stage provides students with an opportunity to communicate what they have learned so far and understand what it means. This lesson introduces vocabulary in context and confronts misconceptions.
- The EXTEND stage allows students to use their new knowledge and continue to explore its implications.
- The EVALUATION stage is for both students and teachers to determine how much learning and understanding has taken place.

NASA eClips™ Guide Lites are designed to support existing curriculum.

Note: The hyperlinks included in this document open PDFs or webpages and may perform differently based on the device being used. Links may have to be cut and pasted into a web browser to open. PDFs and other documents may need to be downloaded to view.

National Education Standards
Next Generation Science Standards (NGSS)
- PS4.B: Electromagnetic Radiation
  - 1-PS4-3: Plan and conduct investigations to determine the effect of placing objects made with different materials in the path of a beam of light.
- PS3.A: Definitions of Energy
  - Energy can be moved from place to place by moving objects or through sound, light, or electric currents.
- **CCC**
  - 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: Cause and effect relationships are routinely identified.

ITEEA Standards
- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

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Nondestructive Testing

What is nondestructive evaluation (NDE)? Nondestructive evaluation (NDE), also referred to as nondestructive testing, is the process of evaluating materials to detect and measure the presence of defects without causing damage to the material being tested. Destructive testing, as its name suggests, results in the damage or destruction of the material being tested. The purpose of nondestructive evaluation is to inspect a material, component, or system to ensure that it is safe and reliable without causing damage to the material or equipment. Nondestructive evaluation is a valuable technique used in a wide variety of science, engineering, and technology fields because both time and money can be saved by studying a material to determine its structural integrity without having to constantly replace the material or shut down operations. The early detection of flaws can prevent severe damage to a component, eliminate inefficiency or failure in a system, as well as guard against injury.

How is NDE used? Nondestructive testing has been used to determine the characteristics and test the effectiveness of new materials, to inspect structures/materials such as bridges and new construction for defects (to prevent failure), and to conduct failure analysis studies on structures or materials. Nondestructive testing has also been used to examine archaeological finds, including the uncovering of drawings on a section of rust-covered slate from the Jamestown, Virginia fort (established in May of 1607). To learn more about this discovery, visit NASA eClips *Our World: NASA at Jamestown*: https://nasaeclips.arc.nasa.gov/video/ourworld/our-world-nasa-at-jamestown.

Fun Fact
Nondestructive testing has been used in the examination of the Statue of Liberty and the crack in the Liberty Bell. It has also been used to authenticate works of art, and to determine the safety of space shuttle tiles for re-entry into the atmosphere.

The Nondestructive Evaluation Sciences Branch (NESB) at NASA Langley Research Center in Hampton, Virginia is one of the world's leading nondestructive evaluation sciences research laboratories for aerospace applications. This group, utilizes sensor systems and physics-based modeling and computational methods to perform nondestructive testing for NASA, other governmental agencies and US industries. Additional NDE labs can be found at every NASA Center. NASA's Office of Safety and Mission Assurance manages the NDE Program to ensure the application of highly capable, state-of-the-art NDE processes that enable NASA program safety and mission success. The NDE Program ensures qualified practitioners, assures correct practices and documentation, and oversees the development of advanced technologies that meet NASA mission needs.

What are some common methods for NDE? Established methods of nondestructive evaluation include radiography, ultrasonic inspection, magnetic particle inspection, liquid penetrant inspection, thermography, and visual-optical testing. While many of the nondestructive evaluation techniques can be very complex, visual examination of a material can be relatively simple. Visual examinations of surface characteristics can be used to detect scratches, cracks, and corrosion in most materials. Polarizing filters, like those used to reduce glare in sunglass lenses, can be used to detect areas of stress in transparent materials such as polymers used to make plastics.

What happens when light passes through polarizing film? When light is emitted from a source, the light waves typically vibrate in all directions and orientations. When this same light passes through a piece of polarizing film, only light waves moving in one direction can pass through the filter. All other waves are blocked. When one piece of polarizing film is placed on top of another, the films will either be transparent or opaque to light depending on whether the films are parallel or perpendicular to each other (see the diagram below). By rotating one film while leaving the other stationary, the light will either be blocked or travel through both films. When the light is blocked, the filters are described as being cross-polarizers.

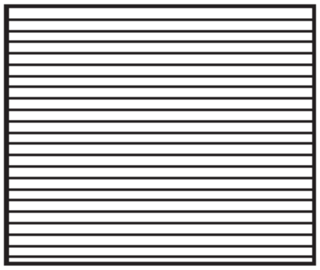


Figure 1: Only horizontally-oriented light can pass through this film.

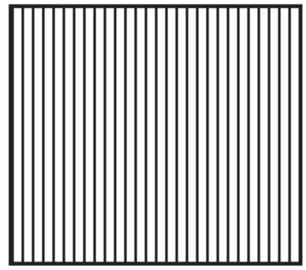


Figure 2: Only vertically-oriented light can pass through this film.

Placing transparent plastics, such as clear cellophane tape or molded clear plastic, between cross-polarizers, produces birefringence. Birefringence is a process in which light moving in different directions, or polarizations, travels at different speeds within a material. Light traveling through transparent plastic materials is split into two waves. Each wave travels at a different speed. The light from each wave is refracted, or bent, as it passes through the polymer, creating a double image of anything viewed through the transparent medium.

When polarized light is passed through transparent plastics that have been compressed or stretched it often produces patches or bands of color known as fringes. This is an example of double refraction or birefringence. These colored bands or fringes can be analyzed to help scientists and engineers understand the degree and extent of stress.

Polariscopes, or strain viewers, are often used to inspect transparent materials, such as plastics and glass, for areas of stress. A polariscope consists of a light source and two polarized lenses. Items being examined are placed between the two lenses and are viewed through the lens opposite the light source.

Polariscope

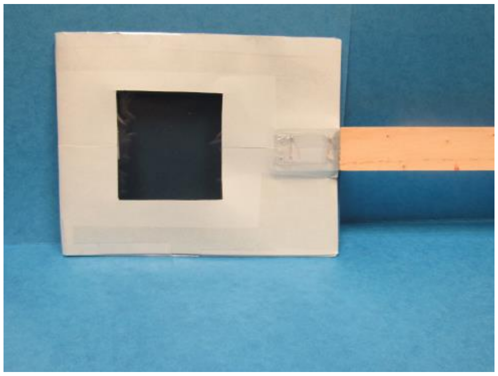
Objective:
Participants will learn how cross-polarizers can be used to view the light refraction and birefringence produced in transparent plastics, a means of nondestructive visual evaluation that can be used to analyze the extent and degree of stress in a clear or transparent plastic material.

Materials:
For class demonstration
<u>Per class</u>:

- index cards (3 x 5” or 4 x 6”)
- clear, cellophane tape
- scissors
- chart paper for posting final vocabulary definitions

To conduct nondestructive testing

Teacher Preparation: Constructing polarizing paddles makes it easier for students to manipulate the polarizing lenses without smudging them. To construct a paddle, cut an opening slightly smaller than the polarizing filter in the center of two pieces of cardstock. Tape the filter in place over the opening on one of the pieces of cardstock. Staple a paint stir stick (easily obtained at home improvement stores) to the bottom center of the sheet of cardstock so that approximately 10 cm of the stick overlaps the cardstock. Use glue or tape to adhere the pieces of cardstock together.



polarizing paddle

Per student:

- Student Nondestructive Evaluation Data Sheet

Per group (2-4 students):

- copy of Frayer Model (alternatively, these can be completed online –- see directions in the Explore section)
- 2 pieces of polarizing film, approximately 7.5 cm x 7.5 cm (available from science supply companies) or polarizing paddles (described in the Teacher Preparation section)
- light source such as a lamp or flashlight that has a flat surface on which to lay the polarizing film (only needed if the room is not well lit)
  CAUTION: Do not use a light source that becomes hot to the touch.
- transparent plastic samples for testing: clear plastic cd case, plastic 6-pack rings, section of polyethylene sheeting (available from home improvement stores), small clear plastic cups (like the ones used for condiments), clear cellophane tape, thin section of mica, plastic microscope slide or cover slip, clear plastic utensils
- colored pencils or crayons

sample materials to test

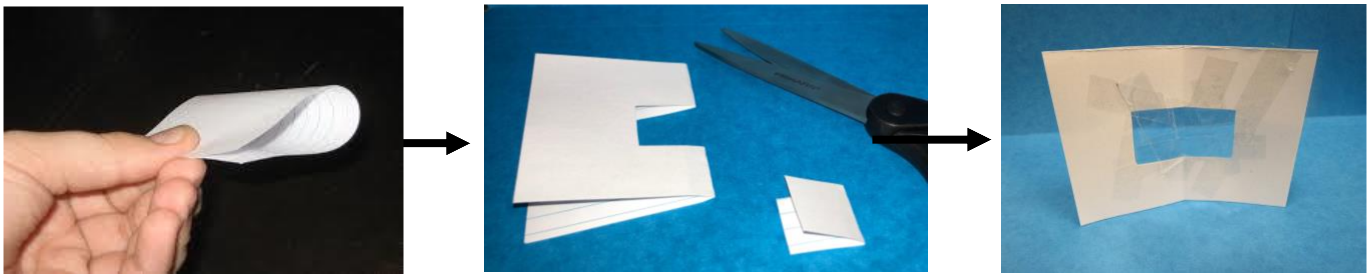
To complete the Extension sculpture

Per group (2-4 students):

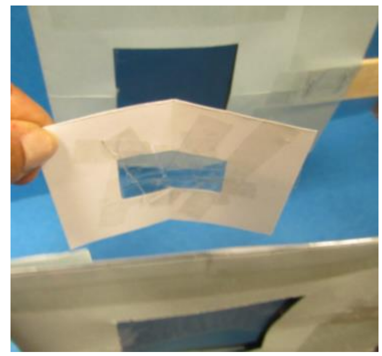
- 2 pieces of polarizing film or polarizing paddles
- light source
- sculpting/florist wire or chenille stems (pipe cleaners)
- cellophane tape

Engage (15 minutes):

To demonstrate birefringence and get students acclimated to using the polarizing paddles, have groups of students prepare a "birefringence slide." Each group should fold an index card in half widthwise and use scissors to carefully cut a small window approximately 2.5 cm x 5 cm (1 x 2"). Cover the opening with multiple layers of cellophane tape affixed in different directions.



making a birefringence slide



Demonstrate how polarizing film works by holding up one piece of polarizing film so that students are able to view light through it. Place a second polarizing film in front of the first (if the room is dark, the polarizing films can be rested on the light source). While keeping one polarizing film stationary, rotate the other until no light passes through the films. When the light is blocked, the filters are described as being cross-polarizers.

Model how to sandwich the "birefringence slide" between two polarizing paddles for testing. (If a light source is being used, demonstrate how the material should be viewed from the side of the film opposite the light source.) The double image produced can be used to introduce the concept of birefringence. As light passes through certain crystalline structures and through transparent plastics that have been stretched, light is split into two paths, creating a double refraction or birefringence. Because holding one polarizing filter and the object being tested while rotating the second filter can be wieldy, ask students to work together to develop the best system for viewing materials.

Identify key vocabulary words and phrases that are essential for an understanding of birefringence. (Examples: birefringence, cross-polarizer, double refraction, light, medium, nondestructive evaluation, opaque, polariscope, polarizing filter, stress, transparent.)

Explore (25 minutes):
Use the Frayer Model to help students develop a conceptual understanding of key vocabulary.

Using a digital interactive Frayer Model enables students to work collaboratively and simultaneously on the same digital document.

Digital Frayer models can be found at:

- PDF Filler: http://tinyurl.com/FrayeronPDFfiller
- Google Slides https://docs.google.com/presentation/d/1a8RaLcmOmSwlYxZBFPWHgbkoEZrJnnp5gicNeElXzjc/edit?usp=sharing

Implementation Note

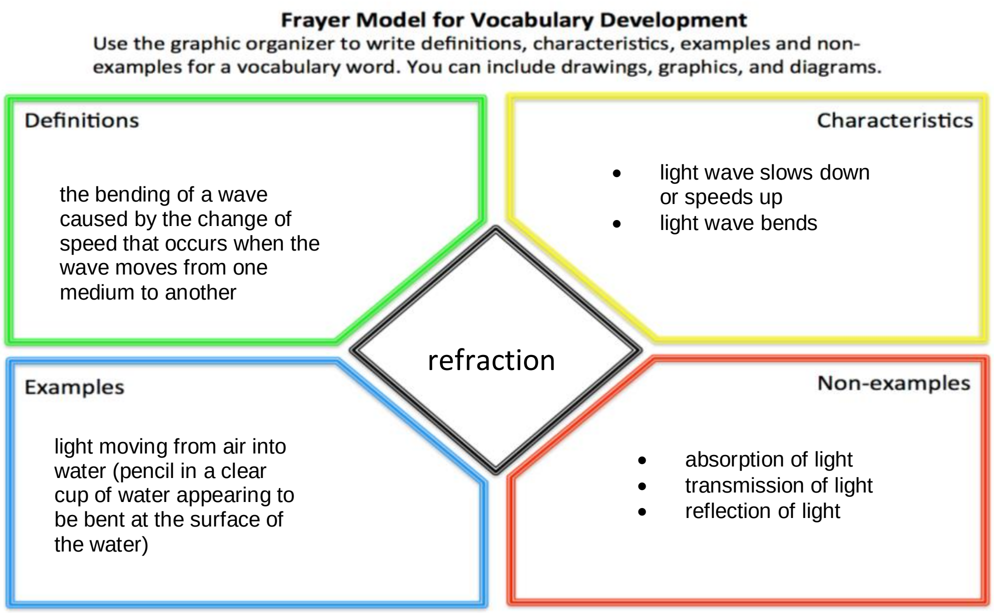
Within the Frayer Model, students EXPLORE concepts through brainstorming and researching and EXPLAIN and synthesize their understanding.

Example: Place the word "refraction" in the center of the graphic organizer. Facilitate a discussion with students exploring why this word is a key vocabulary term for understanding birefringence. Ask students to brainstorm characteristics of "refraction" and add responses to the area with the corresponding heading on the graphic organizer. Ask students to continue their exploration as they research the topic using a variety of resources including their textbook and notes. Next, ask students to add examples and non-examples in the Frayer model. (Emphasize the higher-level thinking skill of comparing and contrasting. How are the examples alike/different than the non-examples?) Using the information provided, ask students to develop a clear concise definition of refraction. An example to guide work can be found below. After completing the example together, assign a new vocabulary word to each group of students. Working collaboratively, students should complete the Frayer Model for each word and share their definitions. Teacher should lead discussions to check for understanding of each vocabulary word.

Definitions and descriptions of highlighted vocabulary words can be found in the NASA eClips Virtual Vocabulary: https://nasaeclips.arc.nasa.gov/teachertoolbox/vocab

Implementation Note

Developing their own definitions helps students build conceptual understanding.



Provide student groups with the materials needed for conducting nondestructive testing (clear plastic compact disc case, plastic 6-pack rings, section of polyethylene sheeting, small clear plastic cups, clear cellophane tape, thin section of mica, plastic microscope slide or cover slip, clear plastic utensils, etc.).

After students conduct their testing, have them discuss their observations and record findings in Table 1 of the Student Nondestructive Evaluation Data Sheet.

Explain (20 minutes):

Have groups share their Frayer Models with the class. Compile final definitions and post them so all students have access for later work.

Student groups report to the class the observations they made during the nondestructive testing.

Ask students:

- What do you think the color bands or fringes that were observed represent?
- Did any material stand out as being more colorful than the others? Why do you think that might be so?
- How do you think scientists and engineers use polarized light or birefringence as a tool?
- Why might it be helpful for scientists or engineers to be able to see defects in a material?

Discuss how polarizing lenses work and how polarized light can be used to visually evaluate clear plastics for defects and areas of stress. Describe how NASA scientists and engineers use visual and other forms of nondestructive evaluation to detect and measure the presence of defects in materials, components, or systems.

To learn how nondestructive testing was used to examine an early artifact from the 1607 fort at Jamestown, Virginia, watch the NASA eClips *Our World: NASA at Jamestown,* which can be viewed or downloaded at: https://nasaeclips.arc.nasa.gov/video/ourworld/our-world-nasa-at-jamestown.

Extend (15 minutes):
Ask student teams to construct their own colorful sculptures that demonstrate birefringence. First, teams should use the sculpting/florist wire, or chenille stems, to create a three-dimensional wire sculpture. Team members should then cover the sculpture with layers of clear cellophane tape, layering the tape as they would for creating a paper Mache sculpture. When complete, students should place the sculpture in front of a stationary polarizing filter. Have one member of the group shine a bright light through the polarizing filter and sculpture from behind. Have another group member slowly rotate the second filter in front of the sculpture until the brightest color patterns are visible. Another team member might use a digital device to take photographs of the display. Ask students to discuss and record their observations in Table 2 of the Student Nondestructive Evaluation Data Sheet.

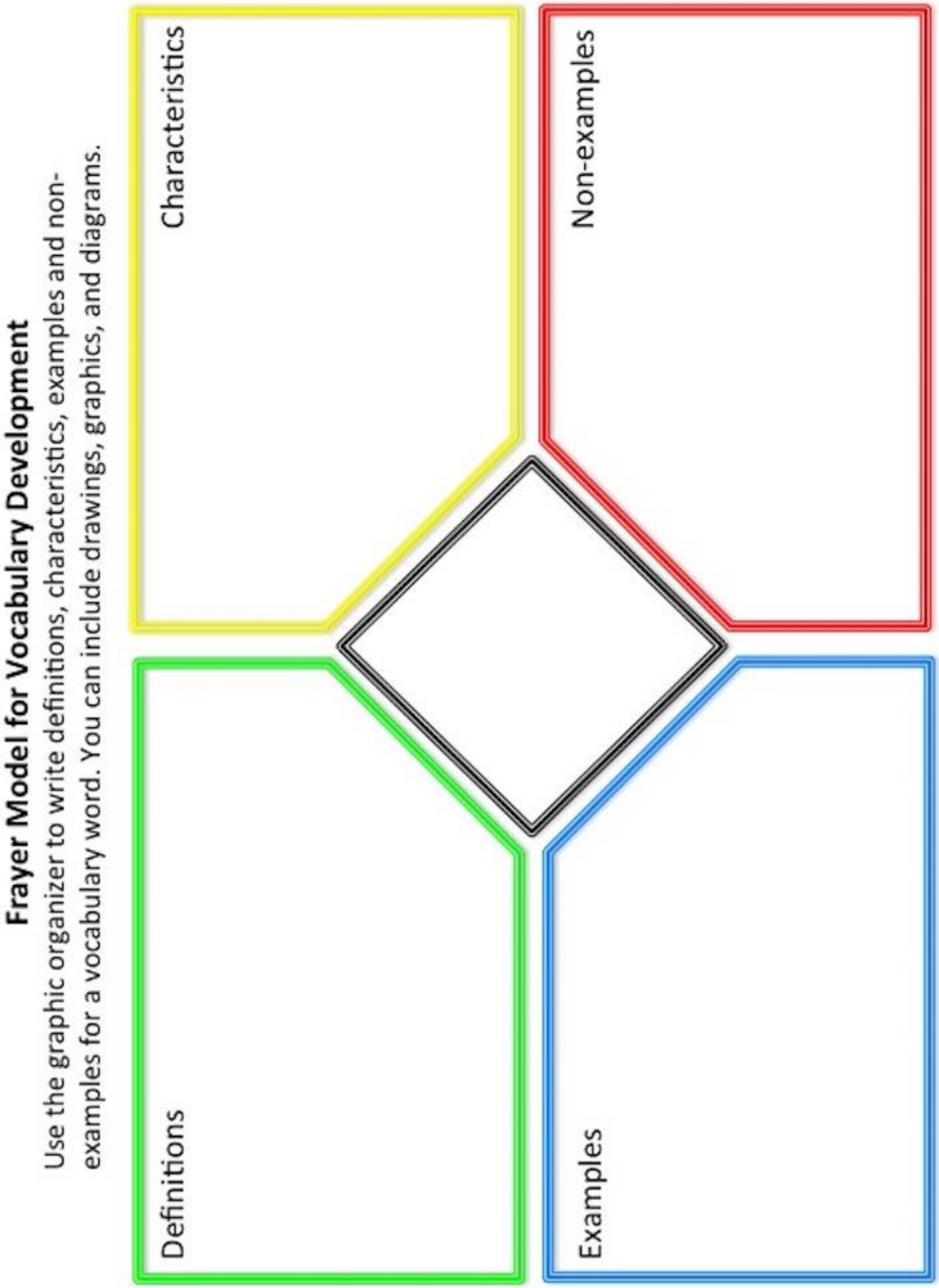
Discuss with students:

- What caused the array of colors produced in the sculpture?
- How did the colors produced in areas of the sculpture with few layers of cellophane tape compare to areas of the sculpture with thick layers of tape?
- Why is nondestructive testing a valuable technology?
- In what ways could nondestructive testing technology be used in your everyday life?

To learn how nondestructive CAT scan technology was used to help archaeologists clear rock from dinosaur remains, watch the NASA eClips *Real World: NASA and a Dinosaur Named Dakota,* which can be viewed or downloaded at:
https://nasaeclips.arc.nasa.gov/video/realworld/real-world-nasa-and-a-dinosaur-named-dakota.

To learn more about birefringence, watch the NASA eClips™ video segment *Launchpad: Thin Ice – Looking at Birefringence,* which can be viewed or downloaded at:
https://nasaeclips.arc.nasa.gov/video/launchpad/launchpad-thin-ice-looking-at-birefringence.

Student Nondestructive Evaluation Data Sheet



Student Nondestructive Evaluation Data Sheet

Table 1	**NONDESTRUCTIVE EVALUATION OBSERVATIONS**	
Material Tested	**Description of Observation**	**Colored Drawing or Photo of Observation**
clear lid or bottom of plastic cd case		

Things to Think About and Discuss with Your Teammates

https://pixabay.com/photo-1184896/

1. What do you think the color bands or fringes represent?
2. Did any materials stand out as being more colorful than the others? Why do you think that might be so?
3. How do you think scientists and engineers use polarized light or birefringence as tools?
4. Why might it be helpful for scientists or engineers to be able to see defects in a material?

Student Nondestructive Evaluation Data Sheet

Table 2 BIREFRINGENCE SCULPTURE	
Description of Observations	**Colored Drawing or Photo of Observations**

Things to Think About and Discuss with Your Teammates

1. What caused the array of color produced in the sculpture?
2. Why is nondestructive testing a valuable technology?
3. In what different ways could nondestructive testing technology be used in your everyday life?

Student Nondestructive Evaluation Data Sheet

Answer Key

Table 1	**NONDESTRUCTIVE EVALUATION OBSERVATIONS**	
Material Tested	**Description of Observation**	**Colored Drawing or Photo of Observation**
clear lid or bottom of plastic cd case	*Example: transparent with a few scratches*	drawings will vary
plastic 6-pack ring	observations will vary	drawings will vary
polyethylene sheeting	observations will vary	drawings will vary
clear, plastic cup	observations will vary	drawings will vary
clear, plastic utensil	observations will vary	drawings will vary

Things to Think About and Discuss with Your Teammates

https://pixabay.com/photo-1184896/

1. What do you think the color bands or fringes represent? *areas of stress*
2. Did any materials stand out as being more colorful than the others? Why do you think that might be so? *answers will vary; darker colors represent areas of greater stress*
3. How do you think scientists and engineers use polarized light or birefringence as tools? *to determine whether materials/structures are stressed and could possibly fail; to analyze materials/structures that have failed*
4. Why might it be helpful for scientists or engineers to be able to see defects in a material? *to avoid failure/breakage of a material/structure; avoid injury*

Student Nondestructive Evaluation Data Sheet

Table 2	**BIREFRINGENCE SCULPTURE**
Description of Observations	**Colored Drawing or Photo of Observations**
answers will vary	*answers will vary*

Things to Think About and Discuss with Your Teammates

1. What caused the array of color produced in the sculpture? *birefringence or the double refraction of light*
2. Why is nondestructive testing a valuable technology? *It can be used to make sure materials/structures are uncompromised and safe*
3. In what different ways could nondestructive testing technology be used in your everyday life? *answers will vary*