

Exploring the Science of Retroreflectivity

Texas A&M Transportation Institute

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Overall Objective

Our goal is to connect real-life applications in transportation to academic concepts to enhance the STEM (science, technology, engineering, and math) learning experience for students.

Connecting the Classroom to the Roads

Kids see signs everywhere. Some signs show businesses, some tell us about a product or service and others help us find our destination. The latter are road signs, and while they may look like ordinary signs, there is some amazing engineering that goes into every one of them. Most drivers and passengers never notice the science behind the signs. This unit seeks to help students use discovery techniques and STEM lessons to better understand the characteristics of light as they navigate through the activities and challenges that follow the history of road safety and innovations. Come along for the ride that guarantees to have your students looking out the windows with a new perspective as they travel!

STEM with Emphasis on the E

These lessons were specifically developed with engineering in mind. This unit is molded to fit the standards of engineering design of NGSS for grades 4–6. Specific NGSS and state standards are incorporated into each division, with extensions and modified lessons included for time allowances and informal education opportunities. Each lesson provides background information, activity plans, a supply list, a timetable, and teacher preparation information. The unit is built out to the 5E model (engage, explore, explain, elaborate, and evaluate) with at least one student activity or lesson per section. Each lesson builds from the one prior and can be utilized in its entirety or broken apart to meet learning and time constraints.

TTI Retroreflectivity Kit for Teachers

While a list of materials is available for each lesson, the Texas A&M Transportation Institute (TTI) has a kit ready to go for your classroom! The kit contains most of the supplies needed to complete these activities in their entirety, including items that may not be readily available in the classroom, and has materials for student activities and teacher demonstrations. Each kit contains returnable and consumable items for a classroom of 30 students and can be customized to meet the needs of several classes. Contact STEM@tti.tamu.edu to arrange pickup or delivery of the TTI Retroreflectivity Kit for your classroom.



RETROREFLECTIVITY



RETROREFLECTION!

RETROREFLECTION FOR GRADES 4-6

LEARNING OBJECTIVE

There is more to transportation safety than meets the eye! There is science behind everything we see. Retroreflection builds upon the more common characteristics of light, including reflection, refraction, absorption, diffusion, and transmission to control light in a way that makes signs and roadway markers more visible to drivers and our streets and highways safer for everyone. Students will understand these concepts through STEM-related activities that guide them in discovering these truths for themselves. They will collect, analyze, and draw conclusions with real and relevant data. They will apply new and prior knowledge to design models to test retroreflection with various materials.

After completing this unit of activities, students will:

- understand the visible light portion of the electromagnetic spectrum.
- understand reflection, refraction, absorption, transmission, diffusion, and retroreflection of light.
- have the ability to collect and analyze relevant data and draw logical conclusions.
- have the ability to design and construct models to test ideas using criteria for functionality, effectiveness, and constraints in materials.
- understand how new technologies help us improve current ideas for increased benefits.
- understand a basic engineering design process including: define, plan, make, test, and reflect.
- understand how engineering for retroreflection connects to careers and real-world problem solving.

FEEDBACK

We would like to hear from you! Please share your thoughts on how you used the lessons and photos of your students completing activities along with completed projects. We also welcome your experience in ways we can work to make the unit even better for teachers, students, and facilitators. Please send information and photos to STEM@tti.tamu.edu.



RETROREFLECTIVITY



Student Activities Grades 4–6

ENGAGE – WHAT DO WE SEE?

Students will investigate what we see and why.

Why is the table black? Why is the chair shiny? Why is the rug blue? What if it is clear? What color is sunlight? What is emission? What is transmission? What is reflection? What is absorption? How do reflection and absorption determine the colors I see?

EXPLORE – HOW DOES LIGHT TRAVEL?

In this lesson, students will analyze more properties of reflection, including angle of reflection, amount of both reflection and absorption, and also diffusion and refraction through various mediums. Some colors are brighter, some are darker. This lesson will allow them to use their observational skills to answer these and other questions based on reflection, absorption, transmission, and refraction of light.

If a laser is pointed at the mirror, what direction will it go? What colors are better at absorbing light? What causes diffusion of light? Can we bend light?

EXPLAIN – CAN WE CHANGE WHAT WE SEE?

In this activity, students will investigate how glass spheres can change what we see and how they can help drivers see traffic signs clearly in the dark.

What makes a sign more visible at night? What colors offer better reflection at night? What is retroreflection? How do we bend and bounce light back to the source from several different angles, using refraction and reflection to our advantage?

ELABORATE – CAN WE CONTROL WHAT WE SEE?

In this activity, students will learn and use the engineering design process. They will design, construct, and test retroreflection on a traffic sign to maximize visibility at night to a driver.

What does it mean to be effective? What are constraints? What are criteria for success?

EVALUATE – CAN WE MAKE GOOD BETTER?

Students will be introduced to new technologies in retroreflection. Even when things work, we are always trying to find better solutions. At Texas A&M Transportation Institution, we strive to develop new ways to make the roads safer for everyone, every day. In this unit, students will compare various retroreflective materials to determine which technologies are the most effective, allowing drivers to see them in time to make safe driving decisions.



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How can I collect data that are meaningful to my investigation? What factors should I consider when comparing the effectiveness of a product? Does my investigation provide the same opportunities for success and failure for all the items tested?



RETROREFLECTIVITY



RECOMMENDED TEACHING TIME

The first three units (Engage, Explore and Explain) are background lessons leading to the retroreflectivity units (Elaborate and Evaluate). Teachers may choose to do all, some or none of the background units dependent upon the prior knowledge of the students.

ACTIVITY	DESCRIPTION	TIME
ENGAGE UNIT	WHAT DO WE SEE?	45–50-minute class
ENGAGE-TD-1	A Rainbow of Light	10–15 minutes
ENGAGE-SA-1	Rainbow Glasses	10–15 minutes
ENGAGE-SA-2	Comparison of Colors, Reflection, and Absorption	20 minutes
EXPLORE UNIT	HOW DOES LIGHT TRAVEL?	45–50-minute class
EXPLORE-SA-1	Angle of Reflection	10 minutes
EXPLORE-SA-2	Diffusion	15 minutes
EXPLORE-SA-3	Refraction	20 minutes
EXPLAIN UNIT	CAN WE CHANGE WHAT WE SEE?	30-minute class
EXPLAIN-TD-1	Light through a Glass Sphere	15 minutes
EXPLAIN-SA-1	Does Color Matter?	15 minutes
<i>EXTENSION-1</i>	<i>Measuring Headlights and Calculating Averages</i>	<i>30–45 minutes</i>
	Retroreflection begins here:	
ELABORATE UNIT	CAN WE CONTROL WHAT WE SEE?	Two 45-minute classes
ELABORATE-SA-1	Engineering Design Process Challenge	1 hour 30 minutes
<i>EXTENSION-2</i>	<i>Building Better Models</i>	<i>20–45 minutes</i>
EVALUATE UNIT	CAN WE MAKE GOOD BETTER?	Three 45-minute classes
EVALUATE-TD-1	Prismatic Retroreflection	10 minutes
EVALUATE-SA-1	A Closer Look	20 minutes
EVALUATE-SA-2	Test Engineering	60 minutes
EVALUATE-SA-3	Sharing Solutions	45 minutes
<i>EXTENSION-3</i>	<i>Creating a Class Retroreflective Sign</i>	<i>30 minutes</i>

UNIT TIME: time required to complete the entire lesson with information, student activities, teacher demonstrations, and lab sheets.

This time does not include extensions.

STUDENT ACTIVITY (SA): time required to complete each individual activity and associated lab sheet.

TEACHER DEMONSTRATION (TD): time required to complete the teacher demonstration and associated lab sheet.

EXTENSION: the estimated time required to complete only the extension activity, separate from the unit time.



RETROREFLECTIVITY



TTI RETROREFLECTIVITY KIT

RETURNABLES:

- Flashlights with AAA batteries (class set of 6)
 - Prism (1 for teacher demonstration)
 - Laser pointers with AAA batteries (class set of 6)
 - Pocket microscopes with AA batteries (class set of 6)
 - Long mirrors 3"x6" (class set of 6)
 - Bicycle reflector (1)
 - Large glass ball and stand (1 for teacher demonstration)
 - Cube corner retroreflector (1 for teacher demonstration)
 - Clear marbles (75)*
 - Colored marbles (approx. 75 each: red, yellow, blue and green)*
 - Reflective material: white beaded (#1), white prismatic (#2), and yellow prismatic (#3) (6 pieces of each type labeled on the back #1, #2, and #3, respectively)
 - Protractors (class set of 6)
- *Please return marbles not damaged or used for the class sign.

CONSUMABLES:**

- Give-aways (class set of 30)
 - Diffraction glasses (class set of 30)
 - White paper (6 pieces)
 - Construction paper (need 6 pieces each of green, red, yellow, and black)
 - Modeling clay (2 lb)
 - Manila folders (class set of 6)
 - Marbles for directional and class signs
 - Aluminum foil sheets (15)
 - Clear plastic wrap (6 pieces)
 - Plastic straws (class set of 6)
- **Please return any consumables not used.

NOT INCLUDED IN KIT:

- Crayons or map pencils
- Scissors
- Glue
- Clear tape
- Extra paper



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300ml beaker or clear drinking glasses (class set of 6)

Materials to make your own Playdoh, if desired

Student lab sheets are available to download and print, as needed.

The amount of materials included in each kit may vary based on class size. The amounts shown are for a class of 30 students.



RETROREFLECTIVITY



FORMAT FOR EACH UNIT

UNIT TITLE

Each unit will begin with the general topic of what you can expect students to learn.

There is a host of questions that students will be able to answer upon completion of the unit.

MATERIALS FOR STUDENTS

Per student: materials

Per group: the kit is designed for a class of 30, 6 groups of 5 students each. Assign groups that work for your students; this is written for 6 groups per class.

MATERIALS FOR TEACHER

These are materials you will need for teacher demonstrations or to provide students additionally as needed or requested.

VOCABULARY

The vocabulary is provided to the teacher and can be presented to students in any manner (e.g., before the lesson, as the lesson progresses).

TEACHER BACKGROUND

This section is intended to help the teachers navigate each teacher demonstration, student activity, and class discussion questions.

Slides are provided to aid teachers in each teacher demonstration, student activity, class discussion questions, and fun facts in transportation. They can be used with the class in their entirety or as needed. All units can be completed without the use of the slides except for fun facts in transportation.

TEACHER DEMONSTRATION: Unit-Number: LESSON TITLE

Each teacher demonstration will include instructions, background information, and provide questions for the students, most found directly on the student lab sheets.

Class Discussion Questions: These questions serve as quick checks for the teacher that students are understanding the concepts presented in the teacher demonstrations and/or student activities. General answers are provided for teachers.



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STUDENT ACTIVITY: Unit-Number: LESSON TITLE

Student activities will describe the activity and objective of lesson. It will also provide teacher insight and special instructions.

COOL FACT: Interesting facts that are associated with lesson.

VIDEOS – TOPIC: Title and Link (Video links are also provided in the slides.)

EXTENSION 1: TITLE

LESSON TOPIC. Extension activities provide additional activities for some units and are unique in their purpose. They serve to provide more real-world simulation, data collection, and math application as well as individual creativity.

FUN FACTS IN TRANSPORTATION (on slides):

These fun facts serve to connect the lessons to the real world of transportation. They can also be used as warm-up activities to preview or review data or as mastery checks to analyze understanding following activities.

STUDENT LAB SHEET

A student lab sheet is provided for each unit. The lab sheet may be used in entirety, act as a guide, used only in portions, all at the discretion of the teacher.



RETROREFLECTIVITY



ENGAGE – WHAT DO WE SEE?

Students will investigate why and what we see.

Why is the table black? Why is the chair shiny? Why is the rug blue? What if it is clear? What color is sunlight? What is emission? What is transmission? What is reflection? What is absorption?

This lesson is designed to introduce students to the visible section of the electromagnetic spectrum and understand that visible light is made up of many colors. Understanding this, students can begin to see how colors are reflected in everything around them.

The lab sheet begins with background information and vocabulary on emission, transmission, and absorption of light. This information should be completed by the students prior to the teacher demonstration.

MATERIALS FOR STUDENTS

Per student: Engage Unit lab sheet; diffraction glasses

Per group: flashlight; various colors of construction paper (white, green, red, yellow, and black); clear plastic wrap; red, orange, yellow, green, blue, indigo and violet crayons* or map pencils*

*Items not included in TTI kit. For this activity, students can write as an alternative to coloring.

MATERIALS FOR TEACHER

Sunlight or white light projector*; prism

*Items not included in TTI kit.

VOCABULARY

White Light: the combination of many different wavelengths of light from the different parts of the visible light spectrum.

Emission: the production and sending out of light or energy.

Transmission: light moving through a medium such as air, water, or glass.

Medium: a substance through which energy or light travels (e.g., space, air, or water).

Absorption: light is not reflected, but instead, taken in and converted to heat.

Reflection: light waves bouncing off of a surface.



RETROREFLECTIVITY



TEACHER BACKGROUND

TEACHER DEMONSTRATION Engage-1: A Rainbow of Light

Hold the prism up to the sunlight or other source of white light in the classroom. Explain that the sun emits light, which is transmitted through various mediums. The sun produces and sends white light through the prism, which separates white light into the component colors of red, orange, yellow, green, blue, indigo, and violet (ROY G BIV). You will need to make sure the light falls onto a white surface for students to view the colors with optimal differentiation. Students will color in the colors and/or write the color for each ray of light on the lab sheet. Explain that we see the colors of a rainbow individually or in combination such as teal, lavender, pink, brown, etc.

STUDENT ACTIVITY Engage-1: Rainbow Glasses

Students will look through diffraction glasses at other sources of white light, such as the overhead lights in the classroom, lamps, etc., and describe what colors and patterns they see. LED light bulbs will produce all the colors (ROY G BIV). This will give each student a more individual approach to the investigation and allow them a unique way to explore the colors of ROY G BIV. There are reflection questions on the lab sheet for this activity. If there is a window in the classroom, remind students to NEVER LOOK AT THE SUN!

STUDENT ACTIVITY Engage-2: Comparison of Colors, Reflection, and Absorption

Students will shine flashlights at various colors of construction paper to determine color and will rank the various colors according to the amount of visible absorption and reflection on the lab sheet. Any color construction paper may be used; white, black, green, yellow, and red construction paper are provided in the kit as they represent common traffic sign colors (choose four colors). The classroom will need to be as dark as possible for students to perform the investigation. Explain the differences between reflection and absorption or have the students define them prior to this activity. Black should absorb the most and reflect the least. White should be the opposite: absorbing the least and reflecting the most. Students have an explanation on their sheet about why each object is the color that it is. Objects appear white when the light reflects; conversely, we see all the colors as the white light bounced back. In black, all the colors are absorbed, and we see no color. For red, green, and yellow, all colors are absorbed except for the red, green, and yellow, respectively, that reflect or bounce back to our eyes, causing us to see red, green, and yellow. The darker colors should have higher absorption while the lighter colors should have higher reflection.

Class Discussion Question: Hold up or point to various objects around the room (or use the slide provided). What color, or colors, are reflected for each object? What color, or colors, are absorbed? How do you know?

FUN FACTS IN TRANSPORTATION:

The fun facts in transportation are located in the slide presentation.



RETROREFLECTIVITY



STUDENT LAB SHEET – ENGAGE

A student lab sheet is available in the 5E format for use at the teacher's discretion.



RETROREFLECTIVITY



EXPLORE – HOW DOES LIGHT TRAVEL?

In this lesson, students will analyze more properties of reflection, including angle of reflection, amount of reflection and absorption, diffusion, and refraction through various mediums. Some colors are brighter, some are darker. This lesson will allow students to use their observational skills to answer these and other questions based on reflection, absorption, transmission, and refraction of light.

If a laser is pointed at the mirror, what direction will it go? What colors are better at absorbing light? What causes diffusion of light? Can we bend light?

MATERIALS FOR STUDENTS

Per student: Explore Unit lab sheet

Per group: flashlight; laser pointer; mirror; protractor; straws; clear beaker* or glass* filled 2/3 with water*

*Items not included in TTI kit.

MATERIALS FOR TEACHER

None.

VOCABULARY (Building from engage)

Diffusion: scattering of light as it passes through a medium or is reflected from one.

Refraction: the bending of light as it passes through a medium.

TEACHER BACKGROUND

STUDENT ACTIVITY Explore-1: Angle of Reflection

Remind students of the dangers of shining laser pointers at each other. All lasers should have a clear path through a medium and to a target.

Students will measure the angle of reflection on a flat mirror to determine the path the light will travel. Students will shine the light from three different angles to the center of the protractor, collect data, analyze and draw conclusions on angles of reflection on the lab sheet. This activity is designed to discover that the angle of reflection is equal to the incident angle of light entering. While the actual angles of incident and reflection are measured from the normal line, or perpendicular 90° mark, this activity will still allow students to see that the light reflects from the mirror at the same angle it strikes the mirror. This works best in a semi-dark room with either clear protractors (supplied) or with markings drawn or taped along each angle to help the students shine accurately along each angle. This can be a bit difficult if the students move too much. Have them round to the nearest 10° .



RETROREFLECTIVITY



Class Discussion Question: We can see the sign ahead because it is daytime. In rural areas, signs are placed 12 feet to the right of the road. At night, when a vehicle's headlights shine on a sign to the right of the road (click to show arrow going from headlight to sign), according to the angle of reflection where should the light end up going? (After some discussion, click to show arrow leaving sign). *As we approach the sign, the reflected light would travel away from the sign at the same angle our headlights struck the surface. This makes the sign difficult for the driver to see at night. Where does the light need to go for driver to be able to see and read the sign at night? Why? Back toward the driver. This is why sign material is engineered to retroreflect, or send light back in the direction of the vehicles.*

STUDENT ACTIVITY Explore-2: Diffusion

Students will shine a laser from a pointer through wrinkled clear plastic wrap to illustrate diffusion of light. What happens to the light as it passes through the medium? The light should scatter in many different ways and directions. In transportation, where would we see this occur: rain, snow, or fog?

Class Discussion Question: Why would you use your low beam (dim) headlights in fog rather than your high beam (bright) headlights? *This activity should help students understand diffusion of light. When light is diffused it scatters. The bright headlights will provide more light for the fog to scatter, making it too difficult for the driver to see the road. The dim headlights provide less light and shine slightly down, under the fog, making the markings on the road more visible.*

STUDENT ACTIVITY Explore-3: Refraction

Students will examine how light travels. They will view light reflecting from straws, as well as light from a laser pointer as they create images in beakers or clear drinking glasses containing water. What happens to the appearance of the straw in the water from different positions? What happens to the path of the light? This investigation illustrates refraction: how would you explain and define refraction? Refraction is the bending of light as it changes speed. As it travels through different objects (the water), the light changes speed and turns as it slows down or speeds up. Rain on signs and pavement marking creates refraction, making them more difficult to see.

For best results, use 300 ml beakers filled with 200 ml of water or equivalent size clear glasses.

The angle of refraction changes with the interaction between the light and the particles in the medium including temperature and wavelength of the light. The light in these examples, as shown by the straw and the laser, bend when they pass through the center of the glass and even more as they pass through closer to the outside of the glass or beaker.

Class Discussion Question: In America, low beam headlights provide a distribution of light to illuminate the roadway in front of and to the right of the driver. There are limits on the amount of light that goes up and to the left. Why? *Vehicle headlights in America help the driver see road signs and pavement markings but prevent light from shining directly into the eyes of drivers in oncoming vehicles. What about in countries where they drive on the other side of the road? In countries where they drive on the left, their headlights would need to shine more to the left.*



RETROREFLECTIVITY



STUDENT LAB SHEET – EXPLORE

A student lab sheet is available in the 5E format for use at the teacher's discretion.



RETROREFLECTIVITY



EXPLAIN – CAN WE CHANGE WHAT WE SEE?

In this activity, students will investigate how glass spheres can change what we see and how they can help drivers see traffic signs at night.

What makes a sign more visible at night? What colors offer better reflection at night? What is retroreflection?

MATERIALS FOR STUDENTS

Per student: Explain Unit lab sheet.

Per group: clear, red, blue, yellow and green marble (one of each color); flashlight; white paper; black construction paper

MATERIALS FOR TEACHER

Glass sphere; laser pointer; white paper; foil; flashlight

VOCABULARY

Retroreflection: light reflected back to its source with a minimum of scattering or diffused light.

TEACHER BACKGROUND:

TEACHER DEMONSTRATION: Explain-1: Light Through a Glass Sphere

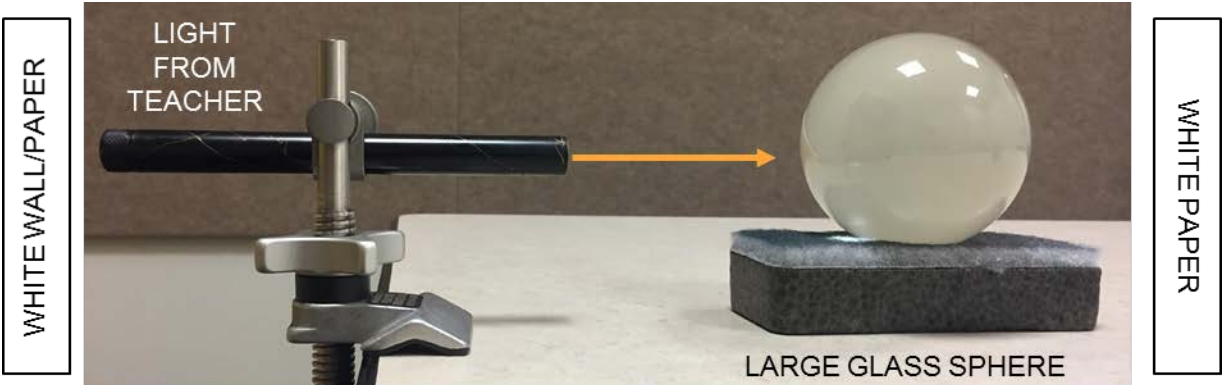
When driving at night, we need signs to reflect light—not at the angle of reflection, but back toward the source in order for drivers to see the signs. We call this retroreflection. Retroreflection uses refraction and reflection to manipulate the light back toward the vehicle’s headlights with some controlled diffusion.

Setup the laser and glass sphere as shown on the next page and in online demonstration. Ensure that there is a white surface (paper) behind the glass sphere and light source (wall or paper). Position yourself near the light source. Position students to the side of the demonstration; their view should be similar to the image on the next page. Make sure the path of the laser is visible to students, but from this angle there should be little to no actual light from the laser going toward the students. However, remind them not to look directly at the laser light. Shine the light such that the students can determine where the light goes as it passes through the sphere. Note: the light will scatter in various directions, so test before class to ensure students are positioned a safe distance away from the demonstration.



RETROREFLECTIVITY





↑STUDENTS↑

Students will illustrate and describe three scenarios:

1. First, shine the flashlight at the sphere representing a vehicle's headlight.
2. Second, shine the laser pointer through the sphere.
3. Third, place a piece of foil in front of the white paper (you can wrap the foil around a file folder to make it sturdier) and again shine the laser light through the sphere.

The glass sphere will bend and reflect the light back toward you and the students. This is retroreflection. You can also wrap foil around the back half of the sphere to increase the effect, but you will need to use the flashlight rather than the laser as the reflected laser may be harmful to your eyes. Don't emphasize this last effect, as students will work to figure out this method in the next lesson. Refer back to the illustration on the lab sheet to verify that the students described retroreflection as light bouncing back toward the source.

STUDENT ACTIVITY: Explain-1: Does Color Matter?

Students discovered through the teacher demonstration that glass spheres can bend and reflect light in a way to create retroreflectivity. But does color matter? Students will place marbles of five different colors (one clear and four additional colors of their choice) onto a white or light colored surface, shine the flashlight into them, and record what they see. They will rank them from 1–5 on how brightly they reflect light.

Class Discussion Questions: Have students discuss this and then allow them time to try it out and see the results. Why did we place the marbles on a white or light colored surface? *The lighter color would not absorb the light from the flashlight but would instead allow it to reflect it back through the marble.*

What if we placed the marbles on a dark surface? Would it change how much light they reflect? *Yes, the darker surface would absorb much of the light, not allowing it to reflect back through the marble and to our eyes. This would make the marble appear much dimmer. While there is*

contrast, the idea here is for the kids to see that light behind and immediately surrounding the marble allows for better reflection of light. Later they may combine this concept with contrasting colors between words/symbols and the background of the sign.

COOL FACT: The marbles light up and retroreflect much the same way as cat's eyes (or many other mammals) when a light shines on them in the dark! The marbles seem to be glowing, but really they are just retroreflecting!

VIDEO – RETROREFLECTIVITY: Retroreflective Materials: MAC RiAus PDplus

<https://www.youtube.com/watch?v=rDRTmymuNyE>

EXTENSION 1: MEASURING HEADLIGHTS AND CALCULATING AVERAGES

FROM THE HEADLIGHTS TO THE DRIVER'S EYES! This activity is recommended for 5th grade and above students and involves data collection and analysis using averages. Students will work in pairs or small groups.

Using a meter stick, have students gather data on 10 different vehicles from the teacher parking lot. Measure the height from the ground to the approximate center of the headlight. Allow each group to select and measure any 10 vehicles of their choosing and calculate the average height. Have the students record their findings and compute an average. Share and compare averages.

Class Discussion Questions: What makes a good sampling of vehicles? How do you know? Why could it be beneficial to get some measurements from many different types of vehicles? A good sampling would include measurements from a variety of vehicles rather than the same type. Even further, the sampling should mimic the percentages of each type of vehicle on the road today.

The average driver sits 1.1 meter or 110 cm above the roadway. Why is this an important number to know? We need to know the average driver eye height so we can calculate the observation angle (angle between headlights and driver's eyes), which impacts the ability of drivers to see traffic signs.

What role does retroreflection play for the driver to see this sign? To see the sign, **retroreflection** must take place.

What properties of light do we see happening in retroreflection? **Retroreflection** is possible with the **emission and transmission** of the light to the sign followed by **refraction, reflection, diffusion** and even some **absorption** around the lettering. The truck needs slightly more diffusion so that the angle of observation is great enough that the light shines up to the driver. The sign will not work with reflection alone, which is where glass beads come in. We do not need absorption in the lettering or transmission through the sign for retroreflection.



RETROREFLECTIVITY



FUN FACTS IN TRANSPORTATION

The fun facts in transportation are located in the slide presentation.

STUDENT LAB SHEET – EXPLAIN

A student lab sheet is available in the 5E format for use at the teacher's discretion.



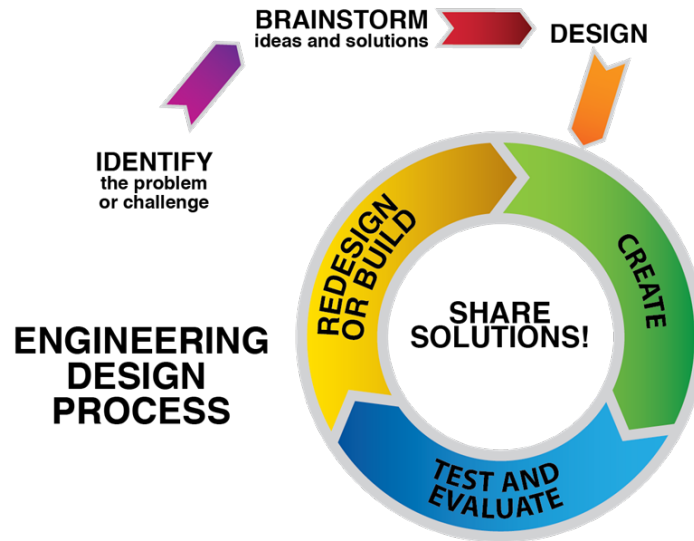
RETROREFLECTIVITY



ELABORATE – CAN WE CONTROL WHAT WE SEE?

In this activity, students will learn and use the engineering design process. They will design, construct, and test retroreflection on a traffic sign to maximize visibility at night to a driver.

What does it mean to be effective? What are constraints? What are criteria for success?



Engineering is about developing solutions to problems and challenges in our world. The Texas A&M Transportation Institute works every day toward solutions in all aspects of transportation. They conduct over 700 research projects each year on land, sea, and in the air.

The engineering design process is fluid. It does not have to begin or end at a particular point. One important aspect of the process is to share solutions along the way with others. Engineering is the design and building of new ideas.

Part 1a: Define the Problem (Team): What is it that you are trying to accomplish? On this challenge, we hope to achieve maximum retroreflection on a sign, so that it is easily visible to drivers at night.

Part 1b: Brainstorm (Individual): All ideas are a good idea at this stage. Here is where creativity is needed, and no reasonable idea is wrong or bad. This part of the process helps students use what they know and combine it with imagination.

Part 2: Design (Individual): Now it is time to work through all of the pros and cons of each idea. Here you will take into account the criteria, constraints, and materials you have available. Keep in mind the objective, what you are specifically trying to accomplish. At this point you will put your design



EXPLORING
the Science of
RETROREFLECTIVITY



to paper with attention to each detail. Does it meet the proper criteria for success? Does it use only materials that are available?

Part 3a: Design (Team): Now it is time for the students to share their ideas with their team. They will need to analyze the best ideas and raise questions/concerns about ideas (in a respectful manner). The teams will combine their ideas into one design and draw it. Each team should also document the materials used. Remind them that they can only use materials from the original list.

Part 3b: Create (Team): The teams will create their signs.

Part 3C: Test and Evaluate (Team): The teams will test out their signs and evaluate the results. Each team will record their own positive (what worked well) and negative (what didn't work well) results. If Extension 2 is not used, each team can simply stand at the same location, turn off the lights, hold a flashlight up, and analyze their results. You can use two flashlights to mimic headlights. Make sure the signs and lights are in the same position for each presentation (height of the observer and sign matters).

Part 3D: Redesign (Team): The teams will think about how they would redesign their signs to solve any problems. Teams should document things they might change and why.

Part 3E: Share Success (Team): Share successful solutions with others. What are some features that the successful projects have in common? What was the best feature on your project? What was the best feature of another project? How could you combine them for even better results? If you had more time, or other resources, how could you improve on your sign?

MATERIALS FOR STUDENTS

Per student: Elaborate Unit lab sheet

Available per group: clear marbles; colored marbles (red, green, blue, and yellow); clay or Playdoh**;
manila folders; construction paper; 1½ sheets of aluminum foil; rulers*; scissors*; glue*; clear tape*

*Items not included in TTI kit. **Item can be made by the teacher for use if preferred to clay.

SPECIAL NOTE TO TEACHER ON MATERIALS

1. Each student group will be allowed 12 marbles of any color.
2. Each group will use one manila folder for the base of their sign. They may add any of the other materials to the sign including various colors of construction paper.
3. If you prefer to make Playdoh rather than use the modeling clay provided, here is an easy recipe for teacher made Playdoh that makes 2 ½ cups:
 - 2 cups plain flour (all purpose)
 - 2 tablespoons vegetable oil



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- 1/2 cup salt
- 2 tablespoons cream of tartar
- Up to 1.5 cups warm water (adding in increments)
- food coloring (optional, leave out for white)
- few drops glycerin

MATERIALS FOR TEACHER

Dark room*; flashlights on stand* or set spot (represents headlights); place to hang sign*

*Items not included in TTI kit.

VOCABULARY:

Effective: successful in producing the desired result.

Criteria: rule(s) or principle(s) for evaluation.

TEACHER BACKGROUND:

Here students will learn the engineering design process to design and construct a retroreflective sign. They will begin by defining the problem and then work toward a solution.

STUDENT ACTIVITY: Elaborate-1: Engineering Design Process Challenge

Students will put their understanding of the engineering design process to work by experimenting with a variety of ideas to make a sign with high retroreflective properties. All students should have the same criteria, constraints, and materials for each sign; however, they should be encouraged to use their imaginations as well. It is also a good idea to allow groups to work privately to provide for a greater number of original ideas when they share with the class. The challenge on the lab sheet simply calls for a directional sign. Some variations to their signs might be spacing of the marbles, depth of the marbles in the sign materials, color of the bead, the background of the sign behind the beads (e.g., plain, foil background, foil molded around the bottom portion of each marble prior to placement).

Each group: Share with the class the best thing about your model. Complete the lab sheet, writing down good ideas learned from other groups.

Class Discussion Question: What factors contributed the most to the retroreflectivity of the sign?

EXTENSION 2: BUILDING BETTER MODELS!

As a class or for each group, design a test car with flashlights for headlights and seats for the driver and front passenger. Use this model to measure the success of the retroreflection for each group's retroreflective sign. Ideas for construction include using chairs and tables, cardboard boxes or a combination of things already found in the classroom.



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Make sure the model cars are far enough away that light can travel to the sign with enough room to retroreflect back to eyes of the drivers. Remember there are large, tall trucks on the road carrying heavy loads.

FUN FACTS IN TRANSPORTATION:

The fun facts in transportation are located in the slide presentation.

STUDENT LAB SHEET – ELABORATE

A student lab sheet is available in the 5E format for use at the teacher's discretion.



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EVALUATE – CAN WE MAKE GOOD BETTER?

Students will be introduced to new technologies in retroreflection. Even when things work, we are always trying to find better solutions. At the Texas A&M Transportation Institute, we strive to develop new ways to improve the safety and mobility of the transportation system for all users. In this unit, students will compare various retroreflective materials to determine which technologies are the most effective, allowing drivers to see them in time to make safe driving decisions.

How can I collect data that is meaningful to my investigation? What factors should I consider when comparing the effectiveness of a product?

MATERIALS FOR STUDENTS

Per student: Evaluate Unit lab sheet; extra paper*

Per Group: sign sheeting materials (one piece each of #1, #2, and #3); flashlight; pocket microscope

*Items not included in TTI kit.

MATERIALS FOR TEACHER

Cube corner retroreflector; laser pointer (video alternative); bicycle reflector

VOCABULARY

Prismatic: having the form of a prism or collection of prisms

TEACHER BACKGROUND

When driving, it is important to see and read signs with plenty of time to react. The type of retroreflective material affects the distance at which drivers can see and read signs. Increases in speed and mass of the vehicle require a longer stopping distance and thus drivers need to be able to see and read the signs from as far away as possible.

TEACHER DEMONSTRATION Evaluate-1: Prismatic Retroreflection

The teacher will show a brief video and/or conduct a demonstration using a laser pointer on a cube corner retroreflector to demonstrate how the prismatic retroreflectors work. This demonstration shows how light is reflected off multiple sides to reflect back toward the light source. You can also demonstrate the retroreflection of the bicycle reflector included in the kit by changing the angle of the flashlight.

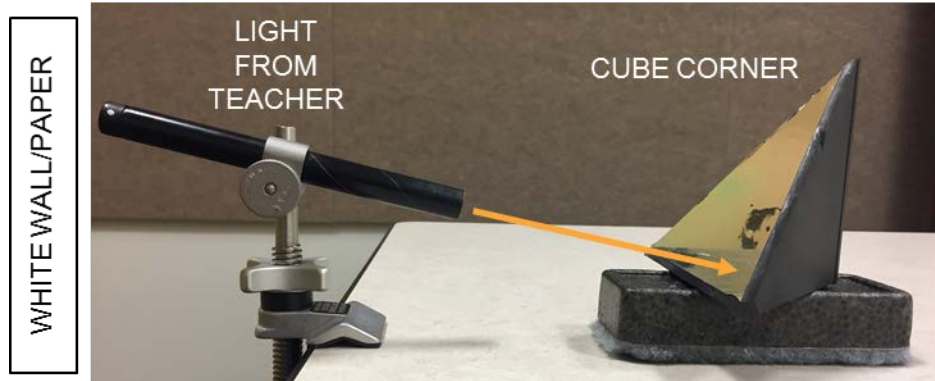
Below is the link to a video that both explains retroreflective cubes and also provides some great visuals!

<https://www.youtube.com/watch?v=S4vYq31cpyc>



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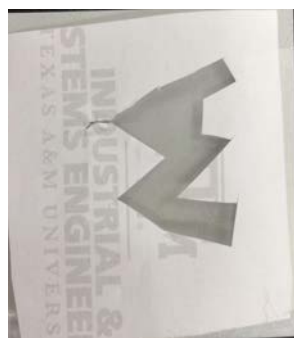
STUDENT ACTIVITY Evaluate-1: A Closer Look

Provide each student group with numbered sign sheeting material (#1, #2, and #3) and a pocket microscope. The students will describe and illustrate what they see through the microscope for each piece of sign sheeting material.

STUDENT ACTIVITY Evaluate-2: Test Engineering

In this activity, students will be challenged to set up their own investigation in order to recommend the most effective retroreflective materials based on their data from the first two activities as well as information collected and analyzed in an investigation of their own. The emphasis on this activity is each group's ability to design and carry out a relevant investigation. They will again follow the engineering design process to develop their investigation and will answer questions provided, as well as their own questions.

The sign sheeting material is all commercial-grade, so it is very bright at close distances making it difficult to tell them apart. Strategies to help students differentiate between the sign sheeting materials include: dimmer flashlights, further distances away from sign sheeting material, and creating overlays with construction paper that can be rotated in different directions (e.g., a letter or shape).



STUDENT ACTIVITY Evaluate-3: Share Solutions

They will share their investigation with the class through a brief presentation, relaying the test they designed along with their findings, analysis, and official recommendation for one of the retroreflective materials (1, 2, or 3). Presentations can vary from oral presentations only to more formal presentations with visual aids.

EXTENSION 3: Creating a Class Retroreflective Sign!

Let's put the A into STEM and move into STEAM! Using glass marbles or beads and/or prismatic materials from the consumable container of the TTI Retroreflection Kit, create a special retroreflective sign or keepsake for the classroom. Ideas include the school mascot, school initials, teacher's name, school name, logos, motivational wording, and more! Hang it up and enjoy! Please share a photo with us. Please would love to see what retroreflection looks like in your class!

FUN FACTS IN TRANSPORTATION

VIDEO Evaluate: The link is found below and also on the slides.

Here is an article and video about one of 3M's engineers who helped develop the retroreflectors of today. He has some great advice on perseverance and creativity when working on engineering projects.

"How the power of perseverance helped lead to a road safety breakthrough"

http://www.3m.com/3M/en_US/particles/all-articles/article-detail/~road-traffic-safety-reflective-signs-visibility?storyid=2cb8314f-358f-4924-800e-cc2b75191237&wt.z_ch=fb&wt.z_cp=applied_to_life&wt.z_mt=photo&wt.mc_id=road+safety2077

Additional fun facts in transportation are located in the slide presentation.

COOL FACT

VIDEO: Retroreflection on the moon!

This extra video shows how we use retroreflectors on the moon and a laser to see how far away the moon is from Earth at any given time! One of the testing facilities is here in Texas!

Mythbusters Moon Hoax Retroreflectors: <https://www.youtube.com/watch?v=VmVxSFnjYCA>

STUDENT LAB SHEET – EVALUATE

A student lab sheet is available in the 5E format for use at the teacher's discretion.



EXPLORING
the Science of
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STANDARDS – NGSS AND TEXAS TEKS

NGSS: Next Generation Science Standards

Engineering Design:

3-5-ETS1-1. Define a simple design problem reflecting a need or want that includes specific criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MS-ETS1-1. Define the criteria and constraints of a design problems with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Science and Engineering Practices:

Asking Questions and Defining Problems – Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

Crosscutting Concepts – Influence of Engineering, Technology, and Science on Society and the Natural World People’s needs and wants change over time, as do their demands for new and improved technologies. *As traffic grows and speed limits rise, there is a greater need for more effective communication from traffic signs.* (3- 5-ETS1-1)

Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. (3-5-ETS1-2) *While there are effective traffic signs, improvement is still possible through new and innovative technologies and resources.*



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Disciplinary Core Ideas:

ETS1.B: Developing Possible Solutions – A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) *Prototypes and shared results between teams offer a wide range of new solutions.*

ETS1.C: Optimizing the Design Solution – Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each can provide useful information for the redesign process, that is, some of those characteristics may be incorporated into the new design (MS-ETS1-3) *When several different options created and tested, engineers can use a multitude of the best results when creating a final, most effective product.*

GRADE SPECIFIC

GRADE 4

4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.

MIDDLE SCHOOL

MS-PS-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Disciplinary Core Ideas

PS4.B Electromagnetic Radiation

When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)

The path that light travels can be traced as straight lines, except at the surfaces between different transparent materials (e.g., water and air, air and glass) where the light path bends. (MS-PS4-2)

A wave model of light is useful for explaining brightness, color and the frequency-dependent bending of light at a surface between media. (MS-PS4.2)



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Texas Essential Knowledge Standards (TEKS)

KNOWLEDGE AND SKILLS

GRADE 4

4.2. Scientific investigation and reasoning. The student uses scientific methods during laboratory and outdoor investigations. The student is expected to:

- A. plan and implement descriptive investigations, including asking well-defined questions, making inferences, and selecting and using appropriate equipment or technologies to answer his/her questions;
- B. collect and record data by observing and measuring, using the metric system, and using descriptive words and numerals such as labeled drawings, writing, and concept maps;
- C. construct simple tables, charts, bar graphs, and maps using tools and current technology to organize, examine, and evaluate data;
- D. analyze data and interpret patterns to construct reasonable explanations from data that can be observed and measured;
- E. perform repeated investigations to increase the reliability of results; and
- F. communicate valid oral and written results supported by data.

GRADE 5

5.2. Scientific investigation and reasoning. The student uses scientific methods during laboratory and outdoor investigations. The student is expected to:

- A. describe, plan, and implement simple experimental investigations testing one variable;
- B. ask well-defined questions, formulate testable hypothesis, and select and use appropriate equipment and technology;
- C. collect information by detailed observations and accurate measuring;
- D. analyze and interpret information to construct reasonable explanations from direct (observable) and indirect (inferred) evidence;
- E. demonstrate that repeated investigations may increase the reliability of results;
- F. communicate valid conclusions in both written and verbal forms; and
- G. construct appropriate simple graphs, tables, maps and charts using technology, including computers, to organize, examine, and evaluate information.



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GRADES 4 AND 5:

4.3 and 5.3: The student uses critical thinking and scientific problem solving to make informed decisions. The student is expected to:

A. in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observable testing, including examining all sides of scientific evidence of those scientific explanations to encourage critical thinking by the student.

D. connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

4.4 and 5.4: The student knows how to use a variety of tools and methods to conduct science inquiry. The student is expected to:

A. collect, record, and analyze information using tools, including calculators, microscopes, cameras, computers, hand lenses, metric rulers, Celsius thermometers, mirrors, spring scales, pen balances, triple beam balances, graduated cylinders, beakers, hot plates, meter sticks, compasses, collecting nets, and notebooks; timing devices, including clocks and stopwatches; and materials to support observations of habitats or organisms such as terrariums and aquariums; and

B. use safety equipment, including safety goggles and gloves.

CONTENT SPECIFIC

GRADE 5

5.6.C: Demonstrate that light travels in a straight line until it strikes an object or travels through one medium to another and demonstrates that light can be reflected such as the use of mirrors or other shiny surfaces and refracted such as the appearance of an object when observed through water.

GRADE 6

6.2. Scientific investigation and reasoning. The student uses scientific inquiry methods during laboratory and field investigations. The student is expected to:

A. plan and implement comparative and descriptive investigations by making observations, asking well-defined questions, and using appropriate equipment and technology;

B. design and implement experimental investigations by making observations, asking well-defined questions, formulating testable hypotheses, and using appropriate equipment and technology;

C. collect and record data using the International System of Units (SI) and qualitative means such as labeled drawings, writing, and graphic organizers;



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D. construct tables and graphs, using repeated trials and means, to organize data and identify patterns; and

E. analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.

6.3. Scientific investigation and reasoning. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions and knows the contributions of relevant scientists. The student is expected to:

A. in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations to encourage critical thinking by the student;

B. identify advantages and limitations of models such as size, scale, properties, and materials; and

C. relate the impact of research on scientific thought and society, including the history of science and contributions of scientists as related to the content.



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