The NASA "Why?" Files
The Case of the
Mysterious Red Light

Segment 2

As the tree house detectives continue their search for clues to solve the mystery of the brilliant red sunrises and sunsets, they go to Jefferson Lab in Newport News, Virginia. At this nuclear physics research facility, Dr. Michelle Shinn demonstrates how light reflects and refracts as it hits various surfaces and how mirrors can bounce light from one place to another.

Franz Harary, the famous illusionist, uses a little magic of his own to transport two of the tree house detectives to NASA Dryden Research Center in Edwards, California where he makes a NASA plane disappear. Once they are returned to Dr. D's lab, the tree house detectives learn the difference between transparent, translucent, and opaque. Understanding what the three words mean leads the tree house dectectives to question why the sky appears blue during the day.

To answer that question, the tree house detectives visit Dr. Peter Pilewskie at NASA AMES Research Center at Moffett Field, California to learn about scattering. This new knowledge propels the detectives to question what could be causing the scattering. They make a final stop at NASA Langley Research Center in Hampton, Virginia to talk with Mark Vaughan, a LIDAR researcher who enlightens them on the main causes of pollution. The tree house detectives are surprised to learn that "Mother Nature" can really kick up her heels and raise some dust!

Objectives

The students will

- understand the difference between reflection and refraction.
- learn about plane, concave, and convex mirrors.
- learn how illusions are created.
- be able to differentiate between transparent, translucent, and opaque.
- learn that the Earth's atmosphere is composed of gases and aerosols.
- understand the effect aerosols have on scattering light.
- learn how aerosols occur in the atmosphere.
- learn how scientists measure aerosols in the atmosphere.

Vocabulary

aerosols - tiny solid or liquid particles suspended in the atmosphere

atmosphere - thin blanket of air surrounding the Earth and containing gases (oxygen, nitrogen, and trace gases), solids, and liquids

concave mirror - a mirror that is curved inward and makes images appear larger and closer

convex mirror - a mirror that is curved outward and makes images appear smaller and farther away

fiber optics - very thin glass created to hold pulses of laser light that can carry 65,000 times more information than conventional copper wire

laser - an acronym for light amplification by stimulated emissions of radiation. Light waves in a laser beam are all identical in wavelength and frequency and the light is truly of one color (monochromatic).

LIDAR - Light Detection and Ranging Laser. Active remote sensing that uses pulses of laser light to detect particles or gases in the atmosphere.

mirror - a flat, smooth surface made by putting a thin layer of silver or aluminum onto a sheet of high-quality glass

opaque - a material that blocks all light rays, preventing a person from seeing through it at all

plane mirror - a mirror with a flat surface in which the image is the same size as the reflected object

reflection - a change in direction when light strikes and rebounds from a surface or the boundary between two media

refraction - the bending of light as it changes speed when it passes from one material to another

scattering - bouncing of light in another direction when it hits a molecule in the atmosphere

translucent - a material that mixes light rays and allows a person to see through it, but not clearly

transparent - a material that does not mix light rays and allows a person to see through it clearly

Video Component

Implementation Strategy

The NASA "Why?" Files are designed to enhance and enrich the existing curriculum. Two to three days of class time is suggested for each segment to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 2 of *The Case of the Mysterious Red Light*, discuss the previous segment to review the problem and what the tree house detectives have learned thus far. Sort information by using the "Need to Know Board."
2. Review the list of questions and issues that the students created prior to viewing Segment 1 and determine which, if any, were answered in the video or in the student's own research.
3. Revise and correct any misconceptions that may

have been dispelled during Segment 1. Use tools located on the web, as previously mentioned in Segment 1.

4. Discuss the two hypotheses that the students generated at the end of Segment 1 and decide if information learned supports their existing hypotheses or if they need to revise them. Choose one of the hypotheses and continue investigating.
5. **Focus Questions** - Print the questions from the web site ahead of time for students to copy into their science journals. Encourage students to take notes during the show to answer the questions.

View Segment 2 of the Video

For optimal educational benefit, view *The Case of the Mysterious Red Light* in 15-minute segments and not in its entirety.

After Viewing

1. Lead students to reflect on the "What's Up?" questions asked at the end of the segment.
2. Have students discuss their hypothesis and determine if they can continue to support it or if a new hypothesis needs to be created. Consider the new hypothesis introduced at the end of the segment by the tree house detectives: If there is pollution in the air, then the sky will be red. Reflect on their choice compared to your students' hypotheses. Ask the students what Jason and Matt meant when they said that their hypothesis was not wrong, but that they needed a "stronger" hypothesis.
3. Choose activities from the educator guide and web site to reinforce the concepts discussed in the segment. Pinpoint areas in your curriculum that may need to be reinforced and use activities to aid students' understanding in those areas. Use the activities to "help" the tree house detectives solve the mystery. Help students see the correlation between the information learned and the clues used to solve the mystery.
4. If time did not permit you to begin the web activity at the conclusion of Segment 1, refer to number 4 on page 13 and begin the problem-based learning activity on the NASA "Why?" Files web site. If the web activity was begun, monitor students as they research within their selected roles and review criteria as needed. Encourage the use of the following portions of the online problem-based learning activity:

   Research Rack - books, internet sites, and research tools

   Dr. D's Lab - online simulation "Additive and Subtractive Colors" and hands-on activities for the home or class.

   Media Zone - interviews with experts from this segment
5. Have students reflect in their journals what they have learned from this segment and their own experimentation and research. If needed, give students specific questions to reflect upon or select an activity or exercise from the "Problem Log."
6. Continue to assess the students' learning as appropriate by using their journal writings, checklists, rubrics, and other tools that can be found at the NASA "Why?" Files web site in the "Tools" section of the educators' area.

Careers

laser physicist
illusionist
magician
research scientist
LIDAR researcher
atmospheric scientist

Resources

Books

Hiner, Mark: *The Red and Blue Illusion Book*: How to Create 3-D Drawings and Other Optical Tricks. Tarquin Publications, 1997, ISBN: 1899618058

Kay, Ketih: *The Little Giant Book of Optical Illusions*. Sterling Publishing Company, Inc., 1997, ISBN: 0806961740

Lynch, David K. and Livingston, William: *Color and Light in Nature*. Cambridge University Press, 2001, ISBN: 0521772842

Cosgrove, Brian: Eyewitness: *Weather*. DK Publishing Inc., 2000, ISBN: 0789457822

Mogil, Michael H. and Discovery Channel: *Weather: An Explore Your World Handbook*. Discovery Books, 1999, ISBN: 1563318024

Web Sites

Atmospheric Sciences-NASA Langley Research Center
Homepage with links to information on LIDAR, atmospheric sciences, educational outreach activities, and video clips on aerosols.
http://asd-www.larc.nasa.gov/ASDhomepage.html

NASA Langley Research Center's Aerosol Trading Cards
Learn what aerosols are, how they are formed, and how NASA uses instruments to collect data on atmospheric aerosols around the globe!
http://eosweb.larc.nasa.gov/EDDOCS/Aerosols/Intro2.html

TERRA- What are Aerosols?
This site describes what aerosols are through text and images and explains how and why NASA studies the atmosphere.
http://terra.nasa.gov/FactSheets/Aerosols/

NASA Ames Research Center
Home of Airborne Remote Sensing. Locate information on Earth science and remote sensing.
http://asapdata.arc.nasa.gov/

NASA Apollo Image Gallery
Archives of Apollo images from each of the Apollo missions.
http://www.apolloarchive.com/apollo_gallery.html

Jefferson Lab-Thomas Jefferson National Accelerator Facility
Research facility built to probe the nucleus of an atom by using continuous high-energy electron beams. The Jeffereson Lab web site also has excellent educational resources for teachers and students that focus on atoms, matter, elements, and physics. It also contains a great online glossary, a virtual tour of the facility, and a listing of internships and workshops for students and teachers.
http://www.jlab.org/

See the Light
This ThinkQuest web site created by kids teaches people about basic principles of light, properties of light, color, and optics.
http://library.thinkquest.org/13405/index.html

Encyclopedia of the Atmospheric Environment
This online encyclopedia is a resource for a range of atmospheric issues, including air quality, global warming, and ozone depletion. The online encyclopedia also introduces the atmosphere and branches out to cover topics such as pollution, the water cycle, wind, and weather.
http://www.doc.mmu.ac.uk/aric/eae/english.html

Activities and Worksheets

On the Web

Pouring a Little Light on the Subject
Activity featured by the tree house detectives that shows how light can reflect within a stream of water.

It's a Bird. It's a Plane. No, it's an Aerosol!
Use this activity to measure aerosols in your atmosphere.

The Zig Zag Race of Reflectors

Purpose

To learn that light reflects

Materials (per group)

1 flashlight
4-5 mirrors

Procedure

1. Place students in groups of five or six.
2. Designate one student to hold the flashlight and the others to hold a mirror about waist high while facing each other in two parallel lines one meter apart.
3. Darken the room and have the student with the flashlight shine the light on the first mirror.
4. The student holding the first mirror will then reflect the light from his/her mirror to the mirror across from him/her. That student will reflect the beam to the next mirror across from him/her and so on, zigzagging the light beam until it reaches the last mirror. Students may need to practice a few times.
5. Once the students have practiced, have a race to see which team can reflect the light to the last mirror the fastest.

Conclusion

1. How is light from the flashlight reflected? ______________________________

____

____

2. How did you get the light to reflect to the next mirror? ______________________________

____

____

3. Discuss whether anything could reflect into the sky and change its color.______________

____

____

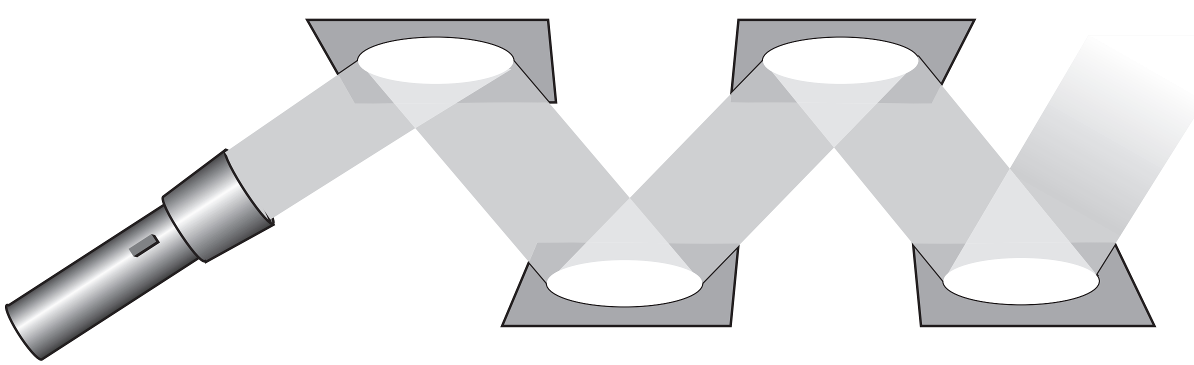
4. How is reflection of light being used in research? ______________________________

____

____

Extension

Students can try to reflect the light in other patterns or alternate the length between the beams.



The Bendable Light

Purpose

To understand total internal reflection of light in fiber optics

Procedure

Teacher Prep

1. Line the bottom of the pan with aluminum foil so that the foil extends over the ends of the pan.
2. Spray the foil and sides of the pan with vegetable oil.
3. Mix 4 packages of gelatin in a large bowl with 2 cups of hot water.
4. Stir with spoon until the gelatin is dissolved.
5. Pour gelatin into the pan about 1.5 – 2 cm (1/2 to 3/4 in.) deep.
6. Place the pan of gelatin in the refrigerator and let set for about 3 hours.
7. Take the pan out of the refrigerator and grasp the ends of the aluminum foil to lift the set gelatin out of the pan and place it on the cutting board.
8. With a sharp knife, cut lengthwise strips about 2 cm (3/4 in.) wide.
9. Carefully lift the strips off the board and give each group 1-2 strips.

Materials

4 packages gelatin desert mix (white grape flavor works the best)
2 cups of hot water
9 X 13 in. pan
aluminum foil
vegetable oil spray
large bowl
spoon
sharp knife
spatula
cutting board
penlight (per group)
index card (per group)

Student Activity

1. Keeping the gelatin flat and straight, shine the penlight through one end of the gelatin. Observe and record.
2. Continue to shine the light through the gelatin and place an index card at the opposite end of the gelatin strip. Observe and record.
3. Gently make shallow curves with the gelatin strip to form an "S" shape.
4. Repeat steps 1-2.
5. If there is more than one strip of gelatin, connect the strips end-to-end and repeat steps 1-2.
6. Gently make shallow curves with the gelatin strips to form a big "S" shape and repeat steps 1-2.
7. Experiment with the gelatin, making the curves sharper until the light no longer travels through the gelatin.
8. In your science journal, write an explanation of what happened.

Conclusion

1. Explain how the light was able to bend when an "S" shape was made? ____________________

____

____

2. If you connected two strips together, did the light shine through the second strip? Why or why not? ____

____

3. Why did the light finally stop shining through the gelatin? ____________________________

____

____

4. What are some uses of fiber optics? ____

____

Refraction Action

Purpose To understand refraction

Materials (5 stations)

3 small, clear containers 3/4 full of water
pencil
ruler
large glass jar 1/2 full of water
3 papers with printed words on them
glass microscope slide
eyedropper
glass baking pan filled with water
white construction paper (9 X 18 in.)
coin
paper towels
activity sheet
index cards

Teacher Prep

1. **Station 1:** Place one of the small, clear containers with water on a flat surface. Insert a pencil and a ruler into the water.

   Station 2: Place the glass jar with water on a flat surface and put a piece of paper with words printed on it beside the jar.

   Station 3: Place a glass microscope slide, eyedropper, small container of water, paper with printed words, and paper towels on a flat surface.

   Station 4: Place a coin in a small container of water and put it on a flat surface.

   Station 5: Draw a horizontal line 10 cm from the lengthwise edge of the white construction paper. Directly below the line and six inches apart, draw and color two identical objects (stars, fish, or flowers). Place the glass baking pan so it covers only one of the objects. You may want to laminate the paper first to keep it dry.

2. On each index card, write a station number and place prominently at each station.
3. Divide your class into five groups and assign each group a station.
4. Distribute activity sheets and have the students write a definition of refraction.
5. Explain to the students that they will be rotating through five stations. When it is time to rotate to the next station, the students should rotate to the next higher number with station 5 going to station 1.
5. Have the students go to their stations. Allow 3-5 minutes for each station and indicate to the students when it is time to move to the next station.

Refraction Action

Light can be reflected and it can also be refracted. Write a definition of refraction:

Refraction is____

Complete the following activities at each station to learn more about refraction. Record your observations at each station before you go to the next station.

Station 1

Look at the ruler and pencil through the side of the glass.

Observations:____

____

Station 2

Hold the printed paper behind the jar and observe the word above the water and below the water.

Observations:____

____

Station 3

Hold the microscope slide over the printed paper. Fill the eyedropper with water and drop one or two drops onto the slide. Observe. Dry the slide.

Observations:____

____

Station 4

Look at the coin in the cup. Move back from the cup until the coin is invisible.

Observations:____

____

Station 5

Look at the paper and its markings. What do you notice about the line and the objects under the pan as compared to those not covered?

Observations:____

____

Conclusion

1. Write a definition for refraction: ______________________________

   ____

2. What causes light to refract an image? Can you list other times you have seen things refracted? ____________________________________

   ____

   ____

3. How will learning about refraction help the tree house detectives?________________

   ____

   ____

Multiple Monies

Purpose

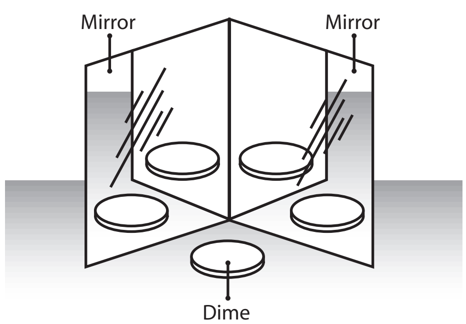
To help students understand how optical illusions can be created

Materials

2 identical mirrors taped together to make a hinge
dime
science journal

Procedure

1. Place the hinged mirrors upright on a flat surface in front of you.
2. Place the dime in the center of the two mirrors.
3. Slowly open and close the mirrors around the dime.
4. Observe and record your observations.



Conclusion

1. What was the least number of dimes that you made appear? ____________________
2. What was the greatest number of dimes that you made appear? ____________________
3. How did the dimes multiply? ____

____

4. Explain how you think magicians might use mirrors to perform tricks. ______________

____

____

____

____

Transparent, Translucent, and Opaque

Purpose

To understand the difference between transparent, translucent, and opaque

Procedure

1. Look at the chart below and for each object predict if it is transparent, translucent, or opaque. Record your prediction.
2. Test each object by shining the flashlight at the object while observing from the other side.
3. Record the results and compare the results to your predictions.

Conclusion

1. Use the back of this sheet to list and make predictions about five other objects in the classroom.

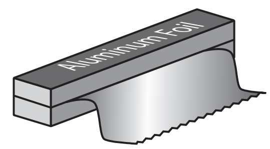
Materials

wax paper
aluminum foil
saran wrap
notebook paper
construction paper
paper plate
clear tape
tissue
glass with colored water
flashlight

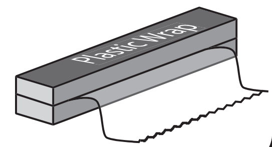
1. Tissue
Predict ☐ Result ☐

2. Colored water
Predict ☐ Result ☐

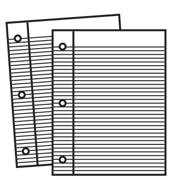
3. Aluminum foil
Predict ☐ Result ☐



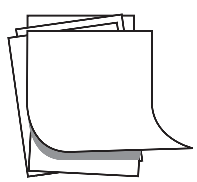
4. Plastic wrap
Predict ☐ Result ☐



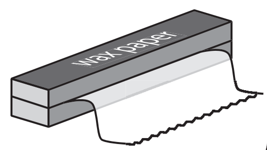
5. Notebook paper
Predict ☐ Result ☐



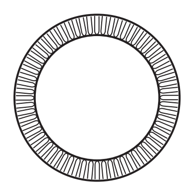
6. Construction paper
Predict ☐ Result ☐



7. Wax paper
Predict ☐ Result ☐



8. Paper plate
Predict ☐ Result ☐



9. Clear tape
Predict ☐ Result ☐

Key

☐ Transparent—light goes through easily
◪ Translucent—some light goes through
■ Opaque—no light goes through

2. Is a cloudless sky transparent during the day? How does it differ from a cloudless night sky?

___

___

3. What type of sky do astronauts see from space? Why? ___

___

Blue, Blue, Where Are You?

Purpose

To learn how aerosols scatter light

Materials

clear glass container such as a jar or beaker
flashlight
small amount of milk
spoon
plain index card
water

Procedure

1. Fill the glass container 3/4 full with water.
2. Place the container on a flat surface and let the water become still.
3. Once the water is still, turn on the flashlight and shine it through the side of the container. Observe the beam of light from the side and from the end.
4. Hold the index card about 30 cm away from the container and directly opposite the beam of light. See diagram. Observe the light as it projects onto the card.
5. Add a spoonful of milk to the water and stir.
6. Repeat steps 3-5.
7. Continue to add spoonfuls of milk to the container until the light will no longer shine through the water.

Conclusion

1. What color was the light as you viewed it through the container of clear water? What color was the light on the index card? ______________________________

____

2. Describe what happened when you added a spoonful of milk. Why? ______________

____

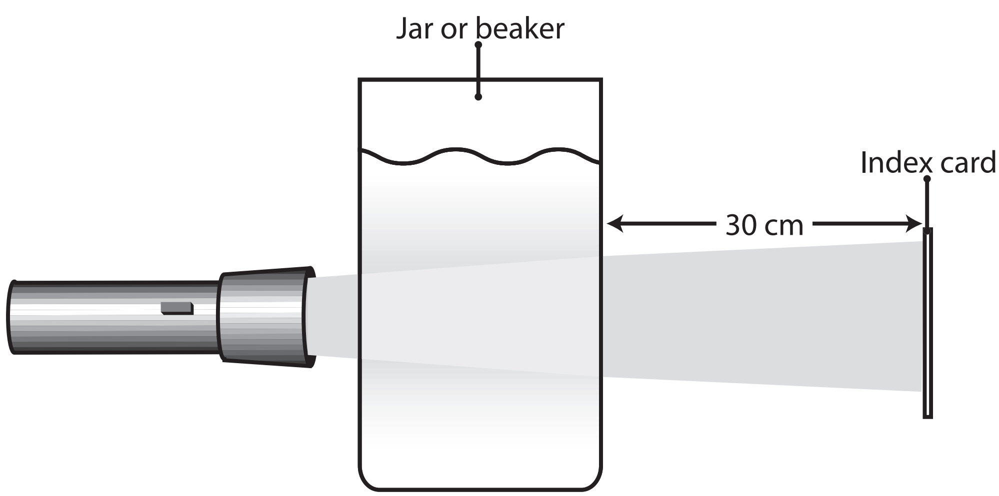
3. Describe what happened as you continued to add milk? Why did this occur? ________

____

4. How can this experiment explain blue skies during the day and red skies at sunrise and sunset? ______________________________

____

____



Answer Key

Zig-Zag Race of Reflectors

1. The light is reflected because it hits the smooth, shiny surface of the mirror. The characteristics of the mirror enable light to bounce off and create what is called reflection.
2. To get the light to reflect to the next mirror, the mirror must be angled and directed toward the next mirror.
3. Things cannot reflect into the sky and change the sky's color. It may appear so at times such as when there is a forest fire. However, the glow from a fire actually acts like a huge flashlight. The light that is created by the fire is really reflecting off the clouds.
4. Answers will vary.

Pouring a Little Light on the Subject

1. The beam of light can be seen in the stream of water as it poured out of the cup. The beam of light entered the water and as the water poured out of the hole in the cup, the light reflected back and forth off the surface of the stream of water, going with the water as it left the cup. This effect is called total internal reflection.
2. Within the stream of water, the light reflected back and forth off the surface of the water.

Bendable Light

1. When an "S" shape was made, the light was able to bend with the shape because it reflected back and forth off the sides of the gelatin and came out the other end.
2. If the strips were "connected" tightly, the light should travel through both strips. If a gap were left, then the light would not have traveled through to the second strip of gelatin because the reflection would have been broken.
3. As you continued to sharpen the angle of the curves, the light eventually escaped because it struck the interior surface of the gelatin at too sharp an angle to be completely reflected.
4. Fiber optics is used for speeding information from place to place, such as via computer or telephone. Cable companies use fiber optics for better television reception, and fiber optics are even used in medicine and research.

Refraction Action

1. Waves do not bend as they travel through a medium. Waves travel in straight lines. However, when waves pass at an angle from one medium to another (air to water), they bend. The waves bend because the speed of the wave changes as the waves travel from one medium to another. Because waves move at different speeds in different densities, the waves bend. The bending of the waves is due to a change in speed and is called refraction.
2. Students may relate incidents such as when they were swimming and their feet looked "broken" or when they were diving for an object and it was not where they reached.
3. Answers will vary.

Multiple Monies

1. The least number of dimes was two.
2. The greatest number of dimes was 14.
3. The dimes multiplied by reflection. When positioned at different angles, each mirror reflects an image that can be reflected again and again. The closer the two mirrors are to each other, the more images they can reflect.
4. Answers will vary.

Transparent, Translucent, and Opaque

1. Answers will vary.
2. A cloudless, daytime sky appears transparent because you can see objects in the air. You can even see airplanes at high altitudes. However, on a cloudless night, you can see the stars. Is the sky during the day really transparent? If it is, where are the stars? Light entering the Earth's atmosphere is scattered by tiny particles suspended in the atmosphere. If there were no atmosphere and no particles to scatter light, we would see a sky similar to the night sky.
3. Astronauts see a sky similar to a night sky, but the Sun is shining. There is no atmosphere in space; therefore, there are no particles to scatter light. To see Apollo mission images, visit **http://www.apolloarchive.com/apollo_gallery.html**.

Blue, Blue, Where are You?

1. From the side the light looks bluish-white, but from the end and on the index card it looks yellow-orange.
2. The beam of light from the side became more yellow-orange, and the light on the index card became more orange-red because the milk created particles in the water that scattered the blue light.
3. The beam of light continued to become a darker yellow-orange, and the light on the index card became even redder because more particles were added to scatter more of the blue light. Eventually, if enough milk is added, the water becomes too cloudy for light to pass through.
4. As light enters the atmosphere, aerosols in the skies scatter light just like the milk particles. During the day, the sky is blue because the particles scatter the blue light. As the sun rises or sets, light has to travel through a thicker atmosphere (more particles), which scatters almost all the blue light, leaving visible only the reddish-orange light. Adding more milk to the container created a thicker "atmosphere" in the jar of water.

It's a Bird. It's a Plane. No, it's an Aerosol!

1. By taking an average of your weekly data, you are able to have a more accurate assessment of the number of aerosols in the atmosphere. Many variables can skew your data. For example, what if a truck with engine problems parked and ran his engine next to your data cards for 20 minutes? That would increase the number of aerosols for that day, but would not reflect a true picture of the atmosphere.
2. It is important to locate the cards in various locations to avoid the problem discussed in number 1. Multiple locations will give you better data.
3. Including other groups' data helps you see if your data are similar. It should be. More data also helps in case you miscounted the aerosols on the card.
4. No, because you do not have any data that tells you what a normal aerosol count consists of. You have nothing to compare your data to. However, if you knew that on an average day, the normal aerosol count was 150 and you had 500, you could assume that something was polluting your air.
5. Many different things could affect aerosol count, such as burning trash or forest fires in the area, a dry, hot, dusty day, or a release of pollutants from a factory.