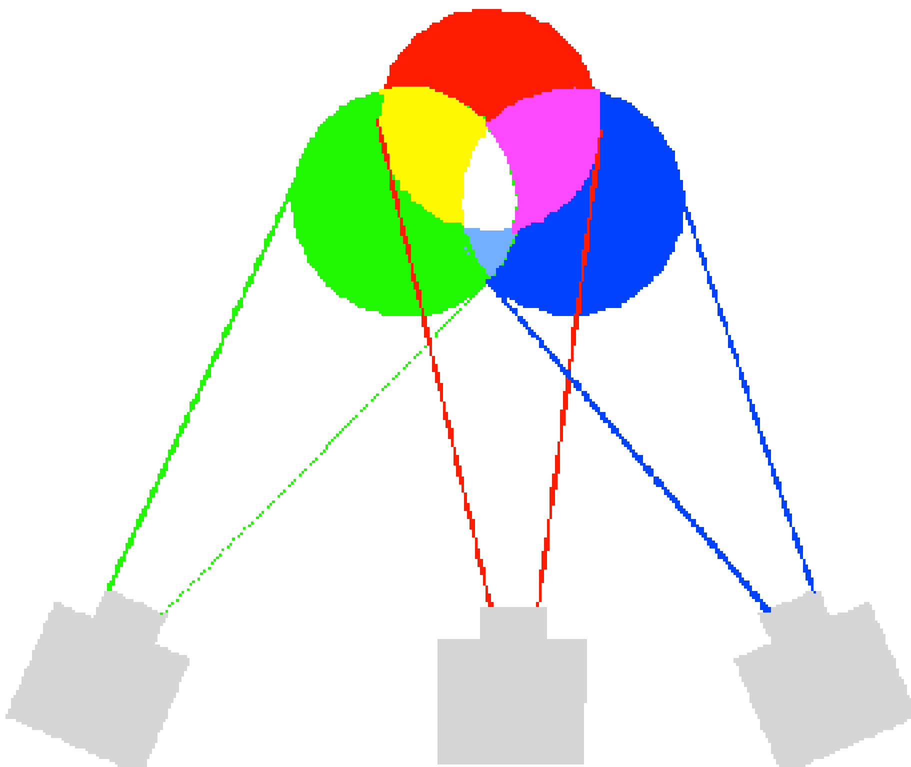
LESSON 1



MIX IT UP

Purpose: Lesson 1, **Mix It Up**, is designed to help your students to understand that the color we see is a particular color of light reflected from an object. This activity will also introduce the concept that white light is a combination of other colors.

Benchmarks for Science Literacy:

- If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but collaboration among investigators can often lead to research designs that are able to deal with such situations. 1B/2 (6-8)
- **Sometimes scientists can control conditions in order to focus on the effect of a single variable.** When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. 1B/3 (9-12)
- **Light** from the sun **is made up of a mixture of many different colors of light, even though to the eye the light looks almost white.** Other things that give off or reflect light have a different mix of colors. 4F/1 (6-8)
- **Something can be "seen" when light waves emitted or reflected by it enter the eye**—just as something can be "heard" when sound waves from it enter the ear. 4F/2 (6-8)

National Science Education Standards:

Grades 5-8

Science As Inquiry-Understanding About Scientific Inquiry

- **Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events**; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.
- **Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.** The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.

Physical Science – Transfer of Energy

- **Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object--emitted by or scattered from it--must enter the eye.**

Background: Many students (and adults) are confused about colors and light. The ancient Greek scientist, Parmenides, believed that light for vision originated in the eye. Another early scientist, Aristotle, wrote that light picks up color from the object from which it is reflected. Some of your students may express these ideas. (Driver, 41-45) Many students do not connect the act of seeing with the arrival of light at the eye. Sources of light (a candle or light bulb) are seen, but students don't think of them as sending out light. Students believe that mirrors reflect, but don't believe that a sheet of paper reflects. (Arons, 226 and Driver, 129) In addition, many people are confused by primary colors. In fact, there are different primary colors for mixing light and for mixing pigments.

There are two critical ideas that need to be understood about seeing color. One is that the eye responds to specific colors (wavelengths) of light. No provision is made to teach this information in this unit, and students may not need to know how the eye works. However, you will probably feel more comfortable if you have some information in case questions arise. To increase your understanding of the eye's response to light, read about "Rods and Cones" and color vision from *Hyperphysics*© http://hyperphysics.phy-astr.gsu.edu/hbase/vision/rodcone.html. The second critical idea is that we see the light that reaches our eye from a direct source or is reflected to our eye. When a traffic light turns red, red light comes directly to our eye. Red paper is red because the paper reflects red light and absorbs other wavelengths. The green paper will reflect green light, and the blue paper reflects blue light. So what happens if red light falls on green paper? Under ideal conditions red light contains only red light and green paper perfectly absorbs all colors but green. Consequently no light will be reflected -the paper will be black! The ideal conditions are remarkably difficult to attain. Unless you have access to pure emitters of red, blue and green light (e.g. lasers), colored light is usually produced by filtering white light, as in this exploration. While red filters tend to be pretty good at filtering out light from the green and blue end of the spectrum, there is some "leakage". Green filters tend to filter blue somewhat, but emit red and yellow. Blue filters that don't also transmit considerable amounts of green and red are extremely difficult to find and are expensive. The transmission spectrum of filters depends upon the filter. You can sometimes obtain the transmission spectrum with the filter. Also, you can check how much and what other colors are coming through a filter by looking at the light from the filter with a spectroscope (see Lesson 3). Similarly, it is difficult to obtain red surfaces that reflect only red, green surfaces that reflect only green and blue surfaces that reflect only blue. These limitations are critical to Activity 1 of **Exploration with Colored Light and Colored Paper**!

When two colors of light are mixed, both colors reach the eye. For example, if a red pixel and a green pixel are right next to each other on your computer screen or if you reflect red light and green light off white paper, the brain will interpret the combination of red light and green light as yellow. (You can see this as you mix primary colors of light with "Colors" at the *NTNU Virtual Physics Laboratory* http://www.phy.ntnu.edu.tw/java/image/rgbColor.html. Another site allows you to use a Java applet to mix colors of light and explore different intensities of red, blue and green light at http://mc2.cchem.berkeley.edu/Java/emission/Java%20Classes/emission.html.)

Pure pigments, however, absorb all colors except the reflected color(s). A pure red pigment subtracts all colors but red. Pure blue pigment subtracts every color but blue. While a mixture of unsaturated red and blue is purple, a mixture of vivid red and blue creates a combination that subtracts all light and you get black. Mixtures of pigments and mixtures of light do different things to light. This is why there are different primary colors for mixing light and for mixing pigments. (For more information visit the *Color Mixing* web site http://home.att.net/~RTRUSCIO/COLORSYS.htm)

The color of light can be correlated with the wavelength of light. The red end of the visible spectrum is around 700 nanometers (nm) and the blue end is around 400nm with a smooth transition from red to red-orange to orange to yellow to yellow-green to green to blue-green to blue to violet. Obviously many different colors have been left out of this description. Every possible wavelength corresponds to a different color even though our eye may not be able to distinguish differences between similar wavelengths, and we certainly have not given names of colors to each distinct wavelength. In fact that would be impossible since there is an infinite number of different wavelengths. Discussion of wavelength is not essential or even appropriate to Lesson 1. Wavelength and the wave properties of light should be developed carefully in separate explorations.

Overview of Student Assignments for Mix It Up

1. **Colors and Light** is a journal assignment to start your students thinking about light. It will also reveal your students' ideas about light.
2. **Exploration with Colored Light and Colored Paper: Predictions** Students make predictions about different experiments with colored light and colored paper based upon the ideas they hold before they begin their explorations.
3. **Exploration with Colored Light and Colored Paper: Data** The students use the Data sheet to record the results of the experiments with colored light and colored paper.
4. **Making Conclusions** Students answer questions that lead them to make conclusions about light and color.
5. **Prediction Reflection** After the exploration is completed and you have discussed the data and conclusions, assign the Prediction Reflection. This will help them to be more aware of their thought process.
6. **Inquiry Reflection – Mix It Up** This reflection is designed to focus the attention of your students on the process and elements of inquiry.

COLORS AND LIGHT: Journal Assignment

Purpose: This journal assignment is designed to encourage your students to think about what they know about light and color. It is also designed to help you to know the commonly held ideas of your students.

Students will begin this unit with a variety of ideas about color and light. Some of these commonly held ideas are discussed in the **Background** of Lesson 1. Students will reveal their ideas if they respond thoughtfully to these questions. Therefore, answers to the journal questions are not right or wrong. The evaluation of the journal should be on the thoughtfulness of the answer and the presence or absence of reasoning to support the answer. This is not a group activity. You will learn much more if each student completes the journal to the best of his or her ability.

Materials:

5 pieces of large sized colored construction paper (one each of red, blue, green, white and black)

Preparation and Procedures:

At the beginning of the class period have each of the pieces of construction paper prominently displayed in the classroom and hand out the journal assignment. Direct your students' attention to the pieces of paper. Allow about 15 minutes to have your students reflect upon and answer the questions. You may assign the journal as a homework assignment. (However, they need the pieces of paper in front of them as they answer the questions.) You know your students best, and you know best which format will achieve the desired goals for this assignment.

Exploration with Colored Light and Colored Paper:

Purpose:

This exploration is designed to help your students to understand that the color we see is a particular color of light reflected from an object. This activity will also introduce the concept that white light is a combination of other colors. Implied, but not proven by this activity, is that the sources of light used (the projector bulb, fluorescent lights or the Sun) emit a mix of many colors of light. Question #7 of **Making Conclusions** directly addresses this question. Do not provide an answer to Question #7. (This idea will be expanded upon in **Prisms and Rainbows**.) Ask students to consider the question as they proceed in their investigation of light. The journal assignment, **Colors and Light,** may have revealed some other ideas that your students have about color and light. Be alert to these as you conduct the exploration. Help them to confront misconceptions by challenging them with evidence that is in opposition to their ideas. Especially use evidence from this lesson.

Materials:

- 5 pieces of large sized colored construction paper (one each of red, blue, green, white and black)
- Red, blue and green gels (gelatin filter), Wratten filters or cellophane (your theater department may help you obtain the gels)
- An overhead projector, 3 slide projectors or powerful flashlights with the colored gels or cellophane fixed securely over the lens. An overhead projector works especially well for Activity 1. If you use an overhead projector, you should get a filter as large as the glass top so that the filter covers the entire surface. Don't put the filter over the upper lens – the heat could melt it. If you use a small filter, use a piece of cardboard as a mask for the glass surface and cut a hole in the cardboard a bit smaller than the filter. You may also use red, blue, and green floodlights from a hardware store. (You will need to check the spectra of the floodlights with a spectroscope because they may project a broad band of wavelengths in addition to the dominant color.)
- A very large (3'x5') sheet of white paper, a white wall or a white board
- A dark room
- **Predictions**
- **Data**
- **Making Conclusions**

(You may wish to run this exploration as a small group activity. In that case you will need 3 flashlights for each group and small size gels or cellophane for each group.)

Preparation and Procedures: Practice these activities before you do them with your students.

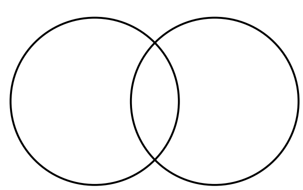
1. Display the 5 pieces of construction paper across the front of the room so that all students can see them clearly.
2. Begin by having the students share their reflections from the journal assignment, **Colors and Light**. Be careful not to communicate that an answer is correct or incorrect, or that one answer is better or worse than another is. Ask questions to help reveal the pre-conceived ideas students have. Different ideas will help stimulate interest in the activity.

3. After sharing the various ideas, demonstrate each filter one at a time. Shine the colored light on the large piece of white paper or on the white board.

4. Have students complete the **Prediction Sheet** in small groups. Walk them through the first combination of red light on red paper to help them understand the task. Ask them to be aware of their reasons for making each prediction. Allow about 15 minutes so that discussion can occur within each group.

   Note: Students may not have much experience making predictions formally. Ask them to think about what they know - what experiences they have had- to guide them. Physics Education Research (PER) has shown that student performance and investment are enhanced when they make predictions. Stress to your students that their predictions will not be graded except for completion and the thoroughness of their answers in Activity 3. Do stress, however, that the predictions are important. Research also indicates that students can learn to learn more effectively if you ask them to reflect upon their predictions after they complete the activity. A **Prediction Reflection** assignment is provided in the Appendix that can be used after any Exploration in which the students make predictions. Introduce the **Prediction Reflection** to students <u>before</u> they start prediction, and tell them a **Prediction Reflection** will be an assignment later on. Ask them to be aware of their reasons for making each prediction in preparation for this assignment.

5. Proceed with Activity 1 of **Exploration with Colored Light and Colored Paper**. Make the room as dark as you can. You can shine the red light on each piece of paper separately, or if you use a projector, you could shine the light on all pieces of paper simultaneously. Caution the students to record what they see and not what they think they should see because they know what the original color of the paper was. The pieces of paper will probably have different shades of dark gray or black. Students should now use the **Data** sheet to record what they actually see. If you shine the light on each piece of paper separately, have a copy of the Data sheet for yourself to guide you. In Activity 1 you will shine the red light on the color of paper indicated in the middle column. For example, you will first shine red light on the red paper, and the students will record the color they see. Then shine the red light on the blue paper, and the students will record the color they see. Continue until you have tested all combinations of Activity 1. Note that you are not shining green light or blue light on the paper. As discussed in the **Background,** green and blue filters that only transmit green or blue light are difficult to obtain. The data obtained from imperfect green or blue filters are difficult to interpret and will introduce unnecessary confusion. However, students may wish to explore the green and blue light on colored paper in their Independent Investigation (Lesson 6)
6. Proceed with Activity 2 of **Exploration with Colored Light and Colored Paper**. Again use the Student Data sheet to guide you. Shine the color of light 1 and the color of light 2 on a white surface so that the colors overlap as shown. Strong flashlights covered by gels or filter can work well.



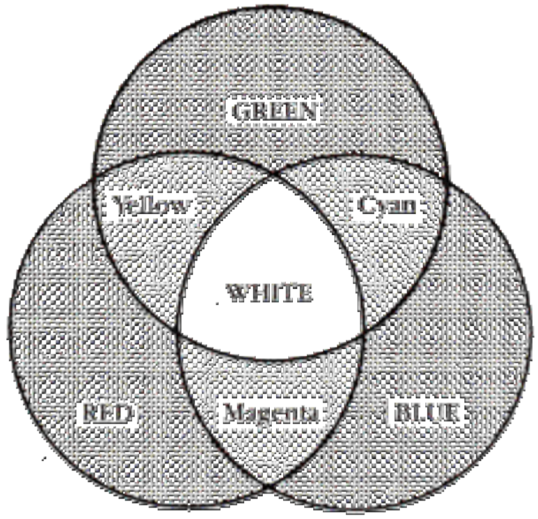
Have students try to describe or match the color in the region of overlap as accurately as possible. Continue until you have tested all combinations.

A mixture of red and green light should look yellow. A mixture of red and blue light should give magenta, and a mixture of blue and green should give cyan. You can observe these mixtures at the*ChemConnections* web site "Emission Spectrum Java Applet". http://mc2.cchem.berkeley.edu/Java/emission/Java%20Classes/emission.html.

7. Open a class discussion to generate solutions to Activity 3 and test the solutions. Have the students record the solutions that work on their Data sheet. (If you run this exploration as a small group activity, this class discussion is not necessary.)

Results:

You should find that overlapping the light from all three sources makes the white paper appear white. If the lights have different intensities, you may see a tinge of the brighter color. Test this before you begin work with the students. You may be able to eliminate any color tinge by moving the brighter projector, flashlight, or floodlight away from the white surface. If you cannot get the right conditions, plan on showing your students that white light is indeed produced by equal balance of red, blue, and green and that any intensity difference will produce a tinge by showing them the *ChemConnections* web site "Emission Spectrum Java Applet". http://mc2.cchem.berkeley.edu/Java/emission/Java%20Classes/emission.html. Where the three colors overlap red, blue and green are reflected to your eye. The color receptors in your eye send signals to the brain that interprets this condition as white light. It is powerful to arrange the lights to overlap as shown below.



This allows a large area of overlap, yet it allows the students to still see the individual colors of the lights reflected off the white paper.

The black color results when no light reaches the eye. This can occur if you turn off the lights. Students may also remember from Activity 1 that black (or nearly black) occurs when red light falls on blue or green paper. However, students may remember from art class that mixing red, blue and green paint produces black – or a dark, muddy brown. This is a difference between mixing colored light and mixing pigments. If they mix red, blue and green pigments, they will get black. However, if they mix red, blue, and green light, they will get white. If this question comes up, schedule a time to go to the webpage "Colors" from the *NTNU Virtual Physics Laboratory* at http://www.phy.ntnu.edu.tw/java/image/rgbColor.html. This website allows you to switch between color mixing and pigment mixing. Another site allows you to use a Java applet to mix colors of light and explore different intensities of red, blue and green light at http://mc2.cchem.berkeley.edu/Java/emission/Java%20Classes/emission.html. You and some of your students may enjoy the webpage "Color and Light" produced by *Patterns in Nature* http://acept.la.asu.edu/PiN/rdg/color/color.shtml. Another good web site to explore color and light is *Color Science* http://www.physics.sfasu.edu/astro/color.html.

8. *Assign* **Making Conclusions**. Remind students that it is important for them to supply reasons for their answers. Remind them to use evidence from the exploration as reasons.

9. After the students have completed their conclusions, engage them in a discussion. Ask them to explain their reasoning as completely as possible. Students may not use the words *reflected* and *absorbed*, but these words may help them to express their understanding more clearly. The sheets of white and black paper serve as special controls. Direct their attention to the controls. An engaging way to begin the discussion (if you can get your room dark enough) is to make the room dark and ask the students what "color" they "see". (They could close their eyes, but that may involve another misconception.) Then ask what conditions resulted in black and why they saw black. Now have them begin to consider the conditions that resulted in color – red light on red paper and white paper, blue light on white, green light on white. Ask them how white paper can be so "flexible" and show the color of the light. If they cannot provide a complete and correct answer, don't supply one and don't tell them the answer is wrong. Go on. (However, by the end of the discussion about Activity 2 and Activity 3 they should be able to answer the question.) If they do supply a complete and correct answer, don't tell them the answer is correct. Ask them if they have evidence from the exploration to support their answer. This should lead you into a discussion of Activities 2 and 3.

   At the completion of this activity, students should understand that we see the colors of light that are reflected. Red paper reflects only red light and absorbs all other colors. White paper can look red in red light, blue in blue light and green in green light because white paper reflects all colors. When red, blue, and green were mixed and reflected, they saw white. So white paper is only white in white light. It is implied, therefore, that room light and sunlight are white light and are made of all colors. This will be explored in **Prisms and Rainbows**, so do not force the issue. Perhaps you can end the discussion with a question: "What color is sunlight and the light from the room lights?"

10. Assign **Prediction Reflection** (Appendix). They should choose predictions from the **Prediction** sheet and compare their predictions with the results from the **Data** sheet. They are only asked to respond to two predictions. The quality of their reflection upon their thought process is more important than quantity.
11. Assign **Inquiry Reflection – Mix It Up**. After they have completed the Inquiry Reflection engage them in a discussion of the structure of the lesson using the Inquiry Reflection. This is a very teacher-centered lesson. You have generated the question. You have provided an experiment that controls variables. The assignment **Making Conclusions** even provides the students with guide questions to help them focus on the most important issues. In Lesson 5 the students have to design everything except the question to be answered, and in Lesson 6 they even have to provide the question. They can learn from the modeling in earlier lessons, but only if you draw their attention to variables, control of variables, the importance of asking questions, and how to make conclusions.