The Benchmarks for Science Education

1. 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.

2. 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.

3. Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation—visible light. Differences of wavelength within that range are perceived as differences in color.

Glossary

Einstein, Albert - was a theoretical physicist whose special and general theories of relativity revolutionized modern thought on the nature of space and time. In 1921 he won the Nobel Prize for his explanation of the photoelectric effect that confirmed both the particle and wave theories of light.

Interference - a behavior of light that occurs when two or more waves overlap. When light waves interfere with each other, the height of the resulting wave depends on the frequencies, the relative positions of the crests and troughs, and the heights of the interfering wave and produces an interference pattern typically with alternating light and dark bands.

Light - Visible light is electromagnetic radiation that has a wavelength in the range from about 4,000 (violet) to about 7,700 (red) angstroms and may be perceived by the normal unaided human eye.

Light Behaviors - include the following: reflection, refraction, diffraction, and interference.

Opaque - a material that does not allow the transmission of light.

Particle Theory of Light - one of two competing theories to explain the behaviors of light, the corpuscular theory, where light sometimes behaves as if it were made up of a stream of small quantities, or quanta, of energy called photons.

Reflection - is the return of a wave, including light, after striking a surface. Reflection is governed by the law that both the arriving waves and the reflected waves travel in directions making equal angles (called the angles of incidence and reflection) with a line perpendicular to the reflecting surface.

Refraction - is the turning or bending light waves when they passes from one medium into another of different density.

Translucent - a material that transmits light with sufficient diffusion to prevent the perception of distinct images.

Transparent - a material that transmits light so that objects or images can be seen as if there were no intervening material.

Wave Theory of Light - one of two competing theories to explain the behaviors of light where light radiation has the common typical properties of wave motion, including diffraction and interference and ranges from waves of extremely high frequency and short wavelength to extremely low frequency and long wavelength.

Review and Extension Questions

1. Describe examples that you have seen supporting the theory that light travels in a straight line until it strikes an object.

2. Describe three different types of behaviors of light.

3. Describe three examples of how light can interact with matter.

4. Describe how the sun is a major source of energy for changes on the earth's surface.

5. Describe an example of how light waves have energy and can transfer that energy when they interact with matter.

6. What evidence do we have that 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?

7. Explain how different object in sunlight can appear as different colors.

8. Explain how something can be "seen" when light waves are emitted or reflected by an object.

9. How does the range of wavelengths of visible light compare with the spectrum of electromagnetic radiation?

10. What characteristic of light causes the different colors that we see.

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TEACHER'S GUIDE

Video Purpose

This video is designed to develop students' understanding of selected light behaviors by using common examples that motivate students to learn more. This video may be used to introduce new concepts, to support learning activities, or to assist with summarizing concepts.

The video provides opportunities to begin inquiring about the nature of light. Video activities help to develop understanding of the behaviors of light. Activities in the video may stimulate students to describe how they would design an investigation, develop explanations based on scientific information and evidence provided through the video, or recognize and analyze several alternative explanations for light behaviors presented in the video. Students need guidance to begin to recognize the relationship between explanation and evidence so that they can understand how background knowledge and theories guide the design of investigations, the types of observations made, and the interpretations of data.

Video Activities:

1. **See Through** - the pieces of a broken beaker mysteriously disappear is an introductory discrepant (counterintuitive) event designed to arouse interest by conflicting with expectations and understanding and to stimulate interest in other possible explanations.
2. **Straight** - demonstrates that light travels in straight lines.
3. **Broken Pencil** - demonstrates the effects of refraction of light.
4. **See Yourself as Others See You** - demonstrates how two perpendicular mirrors can reverse our image to appear like others see us.
5. **Prism** - demonstrates the component colors of white light.
6. **Swirls of Color** - demonstrates how interference can produce spectral colors.

Student Naïve Conceptions

As students grow up they have many experiences for which they form explanations based on a variety of anchoring experiences, such as, seeing rainbows, looking at reflections, and mixing water colors. While these explanations make sense for the student, they may conflict with the results of science investigations, and they are sometimes called naïve conceptions. Student's naïve conceptions should not be treated as wrong as such but as conceptions based on insufficient analysis of their experiences. The activities in this video are designed to help students recognize their explanations and develop a more analytic view. Using models to help understand and explain physical phenomena plays a vital role in science. It is also important to remember that even if they learn all of the terminology, students may sometimes incorrectly apply the experiences they have at the macroscopic level to the microscopic level. Students may only remember the model and not the concept behind the model or attributing the literal behavior of the model to the phenomena that it is supposed to represent.

Telling or showing students the explanations that science uses may not change their beliefs. There are several strategies that can be used to facilitate a deeper understanding. Students need to become aware of their own preconceptions about a concept and expose these beliefs by sharing their ideas with other students in small groups in an uncritical environment to help them begin a deeper analysis of their experiences. They should be encouraged to make predictions based on their conceptions before activities begin. This will help students to begin to confront and test their beliefs and provide motivation for looking for other plausible conceptions. Students need to have time to work toward resolving conflicts between their ideas and their observations, thereby accommodating new concepts. Students need opportunities to extend new concepts by trying to make connections between the new concept and other situations in their daily lives. Students should also be encouraged to go beyond these initial steps by choosing additional questions or problems related to the concept to expand their understanding. These strategies are used to organize suggested activities into the following groups: exposing beliefs, committing to outcomes, confronting beliefs, accommodating concepts, extending concepts, and expanding inquiry.

Sample Support Activities

Exposing Beliefs

Use an activity like "Think, Pair, and Share" to have students begin thinking about their explanations of topics, such as, how an image in a mirror demonstrates that light travels in straight lines, and then share their ideas with a partner. Two pairs can then be combined to share their views and each group of four can have a one person share the different explanations. Moving from small to whole group in a secure and uncritical environment gives students an opportunity to see that others are also uncertain and bring a variety of views to their experience.

Committing to Outcomes

Use the different activities in the video as opportunities to have students predict what they think will happen, for example, the in the "Broken Pencil" activity. Simply stop the video just before the professor places the pencil in the water and have students share with a partner or write their predictions of what will happen. It is important that they make a verifiable commitment so that they can begin to address their beliefs.

Confronting Beliefs

Have students test their ideas by recreating one of the activities on the video or related activities that they found interesting. For example, pairs of students could investigate the "Broken-Pencil" activity and describe their observations and explanations. Working in small groups, students could then debate their explanations, conduct interviews, and check written materials before presenting their results. This is an opportunity for students to confront their beliefs.

Accommodating Concepts

Students need to begin to question their observations and their discussions to help them process information and begin to make sense of the explanations behind the observations. During this time, students begin to resolve the conflict that may exist between beliefs and observations. Class presentations of observations of activities and explanations along with carefully posed teacher questions and follow-up small group discussions will assist with the process of accommodating new concepts.

Extending Concepts

Asking students to give examples of where they have seen the concept discussed or demonstrated or giving examples of how they thing the concept is connected to other situations will help students extend their understanding of the concept. Students could describe situations where they have seen different colors produced similar to the "Swirls of Color" activity.

Expanding Inquiry

To encourage students to continue thinking about the concept, opportunities should be provided that invigorates them to investigate additional questions and problems that interest them.

Correlations to National Standards

The video activities and content address the following National Science Education Standards or The Benchmarks for Science Education *

National Science Education Standards

1. Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by the object.
2. 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.
3. The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.
4. Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.