3-5: Seeing the Light

Curriculum Connections

Physical Science
- Observe, investigate, and describe light: how it is transferred, what happens when objects interact with light

Scientific Communications
- Acquire information from observation, experimentation, print and non-print sources
- Use information gathered from experiments and other sources to explain observations and events, including actively listening for alternative interpretations and ideas

** Based on the New York State Elementary Science Core Curriculum and the New York City New Standards™*

National Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Light, heat , electricity and magnetism
- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

Content Standard C: Life Science
- Structure and function in living systems
- Diversity and adaptations of organisms

Content Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

3-5 Exhibits List

Bridge Light
Color Removal
Convection Current
Diffraction Grating
Disappearing Glass Rod
Hot Light
Laser and Optics Demonstration
Lens Table
Light Island
Magic Wand
Recollections
Soap Films
Sophisticated Shadows
Spectra
Visible Effects of the Invisible
Violin Patterns

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Guide Theme

The theme of these guides are based on popular crime and detective show investigations on TV; a mystery unfolds, questions are asked, evidence is gathered, conclusions are drawn. This process is similar to what scientists go through with the inquiry method. For more details see About the Guides.

Begin the Investigation At School

A mystery unfolds, questions are asked...

There are several ways you can introduce the topic and start the investigation. Here are some ideas that will help students start thinking about the topic and generate questions:

- Create a mystery about the fact that only ten percent of the electrical energy of a light bulb emits light. What does the other ninety percent do? (Mystery solved at Hot Light exhibit)
- Create a mystery about light traveling in waves. Waves? Is it possible to see light waves? (Mystery solved at Bridge Light, Soap Films exhibits)
- Create a mystery about how white light is made of many colors. How is this possible? (Mystery solved at Color Removal, Diffraction Grating, Light Island exhibits)
- Create a mystery around the question; If an object does not emit it's own light, how do we see it? (Mystery solved at Magic Wand and Recollections exhibits)
- Demonstrate one of the Laboratory Activities with no explanation-let the questions begin
- Do one of the Laboratory Activities and facilitate a probing discussion

Prepare for Investigation at the New York Hall of Science

Once students have generated questions around the topic tell them they are going to continue the investigation at the New York Hall of Science.

At this point you may want to begin one of the Continuum Activities. These activities have the following features:

- Vary in length and depth
- Provide continuity and purpose for the visit
- Provide a way of assessing student understanding

Orientation and Planning: If you do nothing else, do this!

Here are five reasons to conduct student orientation and planning before going on a field trip:

1. Students focus on exploring and investigation versus the novelty of the location
2. Students don't have to worry about logistics like restrooms, schedule, eating etc.
3. Students who understand the plan and purpose of the visit are more likely to stay focused
4. Students who have clear goals for their visit are less likely to race from one exhibit to another with little understanding
5. Students who get involved in the planning of the visit, take ownership and are less likely to misbehave

Read more about the Orientation and Planning Process

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Investigation at the New York Hall of Science

Evidence is gathered...

Okay. The class has arrived at the next phase of the investigation. The students have questions and seek answers. Everyone knows what exhibits they should visit and why. Everyone knows the schedule for the day. Students have materials to record findings or work on a Continuum Activity if required.

If all of the above is true, congratulations on a successful Orientation and Planning.

If you are curious about what teachers can do on site, we've put together a little piece called Teacher Role.

Finish the Investigation Back at School

Conclusions are drawn...

There are several ways you can complete the investigation. Some require less time than others. Here are some ideas:

- Student or group oral or written reports on investigation questions and answers
- Student or group illustrations of visit with answers to questions or mystery
- Do one of the Laboratory Activities
- Complete the Continuum Activity

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Continuum Activities

Continuum Activities are designed to carry through the entire investigation. Some activities require less time than others.

Investigation Map

Description: Detectives will often map out related events, evidence and suspects during an investigation. This helps them get an overall picture. Students can map out their investigations with a concept map. The concept map will help you assess what students learn.

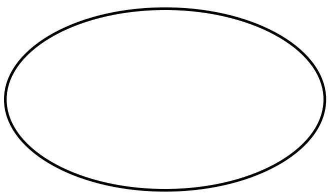
Time: (3)15-30 min. Sessions

Materials Needed:

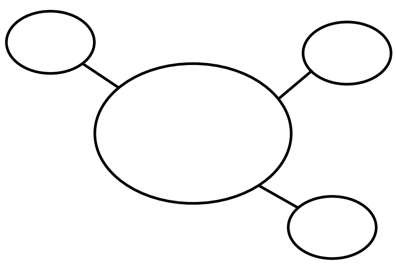
- Blank paper
- Pencils, colored markers

Procedure:

1. Begin with a center circle and write in the name of the main topic. (Students who do not write can have an adult assist or draw a representation of the main topic)



2. As students generate questions about the topic, they can add offshoot circles. They can also add circles for facts they know about prior to the visit to the New York Hall of Science.



3. When students return from their investigation at the New York Hall of Science they add additional circles of information. Their final map should reflect everything they know about the topic. Teachers can easily assess what is learned based on how the map develops.

Investigation Journals

Description: Investigation journals provide a way for students to record their questions and findings throughout the investigation.

Time: (3)15-30 min. Sessions

Materials Needed:

- Blank or lined paper
- Pencils, pens or colored markers
- On-Site Investigation Handout (print out from this web site and make copies)
- Zip-lock bags (for on-site handout only)
- Soft yarn or thick soft string (for on-site handout only)

Procedure:

1. Ask students if they have ever seen a detective take notes when trying to solve a mystery. Tell students that as "science detectives" they too will make a record of the mystery.
2. Have students begin their journal or report with questions that are generated when they Start the Investigation at School.
3. Students who do not have writing skills can make a large question mark and draw representations of their questions. If an experiment or demonstration is done, non-writing students can sketch what they observe.
4. Older students with writing skills can list their own and other students questions in their journal.
5. We strongly advise students not bring journals to the New York Hall of Science where they can get lost. We have provided an On-Site Investigation Handout that can be copied if students want to record observations or make sketches.
6. When students return from their investigation at the New York Hall of Science have them write answers to questions or draw what they observed.

Science TV- Investigative Reporters

Description:
In this activity, students plan and produce a TV show featuring investigative reports on the topic. This is a cooperative learning activity that integrates language arts, science and technology. There is a significant amount of writing involved, however students who are not prolific writers can also contribute as camera people, script supervisors, directors and on-camera reporters. Students will video tape at school and at the New York Hall of Science so pre-planning is essential for this activity.

Time: (3) 45 minute sessions (writing)
(1) video shoot at school
(1) video shoot at the New York Hall of Science
(1) 45 minute session (writing)
(1) video shoot back at school
(1) 30 minute session for viewing final TV show

Materials Needed:

- Video camera
- (1) video tape per student group
- External wired microphone for camera (optional but suggested for good audio)
- TV
- Cables to run camera to TV for viewing
- Student internet access (optional for research)
- Lined paper and pencils
- Large plain paper and markers (cue cards)

Procedure:

First Session-Planning

1. Tell students they are going to plan and produce a TV show with investigative science news stories that are 4-5 minutes in length.
2. Divide the class into groups of four or five students.

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3. Have students or the teacher chose a writer/script supervisor, camera person, director and on-camera reporter for each group.
4. Tell students about the various roles in the production team:
   - Writer-writes groups ideas for script, makes revisions
   - Cameraperson-operates camera
   - Director-supervises camera person and on-camera reporter, calls for action and cuts
   - Script Supervisor-makes cue cards for on-camera reporter, makes sure script is followed
   - On-Camera Reporter-person who reports and appears in video
5. Tell students that everyone the group will work together to create the script.
6. Remind students of the topic of study and the trip to the New York Hall of Science.
7. Instruct students to begin to create questions around the topic for the news show. They may want to create questions for interviews with New York Hall of Science "Explainers" too.
8. Tell students to watch the local news on TV so they can observe how news reporters do their job.

Second Session-Location Scout and Scriptwriting

1. Tell students they are going to do a location scout of the location they will be shooting at the New York Hall of Science. Scouting the location will help them think of more questions and give them ideas for what to shoot on location.
2. Make prints outs of the exhibits the class will visit at the New York Hall of Science OR have students access the exhibits online themselves.
3. Once students have become familiar with the exhibits, allow time for more scriptwriting. Make sure scripts have the following components:
   - Introduction to the report (name of reporter, where they are, news headline)
   - Questions the investigative report will answer
   - Conclusion (to be done after video shoot at New York Hall of Science, comment, opinion about answers, reporter sign-off)

Third Session- Rehearsals and Final Script

1. Remind students about the various roles in the production team:
   - Writer-writes groups ideas for script, makes revisions
   - Cameraperson-operates camera, responsible for video tape
   - Director-supervises camera person and on-camera reporter, calls for action and cuts
   - Script Supervisor-makes cue cards for on-camera reporter to read, makes sure script is followed
   - On-Camera Reporter-person who reports and appears in video
2. Have groups rehearse their roles using the scripts. (Camera people can use their hands to frame shots)
3. Advise groups to make script revisions if they notice problems during rehearsal.

4. Rehearsals can be done in front of whole class or in individual groups depending on your classroom space and noise level.
5. After rehearsal have groups meet and finalize the pre-New York Hall of Science script.

Homework
Have groups give script supervisor the pre-New York Hall of Science script so they can make cue cards. (Script supervisor can ask others to help make cue cards too)

Video Shoot at School
During this session each group will shoot the introduction to their news story. Each group will have their own video tape. Make sure each group tape is labeled. If possible you may want to have groups shoot in a quiet separate location from the others or schedule group shoots during breaks in the day. If the entire class is present during shoots, make sure the others are quiet and don't distract the shooting. After shooting make sure camera people return the group tape to the teacher for safe keeping.

Video Shoot at the New York Hall of Science

1. Make the shooting schedule for the day.
2. Allow 15-20 minutes for groups to shoot in their location.
3. Choose a central location for production groups to meet the adult who will have the video camera and group tapes.
4. Make sure production groups stay together at the New York Hall of Science and Chaperones know the schedule for the day.
5. If students plan to interview a staff "Explainer", locate the Explainer in the area before shooting and ask for their assistance and cooperation for the shoot.
6. After shooting make sure camera people return the group tape to the adult for safe keeping.

Conclusion Script Back at School

1. Production groups will need to write the conclusion to their video script after their New York Hall of Science video shoot.
2. The conclusion should include a summary or opinion of the overall story as well as the reporter sign off.
3. Allow production groups to review their video footage (if necessary) so they can form opinions or summaries.
4. Have script supervisors and others in the group make up the final cue cards and conduct short rehearsals.

Video Shoot at School
During this session each group will shoot the conclusion to their news story. If possible you may want to have groups shoot in a quiet separate location from the others or schedule group shoots during breaks in the day. If the entire class is present during shoots, make sure the others are quiet and don't distract the shooting. After shooting make sure camera people return the group tape to the teacher for safe keeping.

View the Show
Hook up the camera to the TV and run the group tapes from the beginning. Enjoy the show.

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Become an Explainer

Description: Students investigate one exhibit with the goal of being able to explain it when they return to the classroom. Students can choose a variety of methods to explain and make presentations.

Time: (1) 30 min. Session
(2) 45 min. Sessions (for in-class presentations)

Materials Needed:

- Interesting objects (used for student observation)
- Print outs of On-Site Investigation Handout
(optional suggestions)
- Variety of craft materials Variety of craft materials (pipe cleaners, popsicle sticks, straws, string, paints)
- Variety of clean, household recyclables (meat trays, cardboard tubes, aluminum foil, plastic wrap)
- Any other odds and ends students can construct with
- Poster board or paper
- Markers, crayons, colored pencils

Procedure:

First Session

1. Tell students as they will be investigating exhibits at the New York Hall of Science and will choose one exhibit to explain to the class when they return. (students can work in groups or individually)
2. Help students prepare for careful observation of exhibits by distributing interesting objects.
3. Now ask students to verbally describe what they see. Encourage details.
4. After students have described the object in great detail, tell them they will need to use these same observation skills when they are investigating their chosen exhibit.
5. Lead a discussion on what students can do at the New York Hall of Science to help explain and record what they see. Ideas include:
    - Sketching
    - Writing
    - Using exhibit pictures on this web site
    - Photography
6. Distribute The On-Site Investigation Handout (if needed) for use at the New York Hall of Science.
7. Go to the New York Hall of Science.

Second Session

1. Upon return to class from the trip, tell students they will spend time preparing to explain one of the exhibits they saw.
2. Here are some suggestions for student presentations:
    - Verbal explanation (with or without picture)
    - Labeled diagram
    - Group or individual poster showing how an exhibit worked
    - Group or individual model using materials to represent exhibit (materials can be used to

substitute and represent real materials from exhibit— ex. Clear plastic wrap simulates glass, cardboard tube becomes a rocket etc.)

Third Session (optional)
Use this time for students to make their class presentations if they made posters, drawings or models.

Laboratory Activities

Laboratory Activities are designed for the classroom and generally require simple materials. These activities can be done before or after a visit to the New York Hall of Science. To help students use higher-level thinking and generate questions, facilitate discussion with these types of questions:

- What do you notice here?
- Tell me about this.
- What do you see?
- Why do you suppose this happens?
- What can you conclude from the evidence?

Smooth and Rough Reflections Demonstration

Description:
Students observe how light acts differently when it reflects off of a smooth surface as opposed to a rough surface.

Time: (1) 15 minute session
(1) 45 minute diagramming session (optional)

Materials Needed:

- Small mirror
- Flashlight
- Clear glass baking dish
- Water

Preparation:

1. Fill the glass baking dish with water.
2. Prep your demonstration area with the small mirror, glass dish with water and flashlight.

Procedure:

1. Tell students you are going to do a demonstration followed by a quiz and the only question they have to answer is why.
2. Turn off the classroom lights.
3. Turn on the flashlight and point the beam on the mirror's surface.
4. Tell students to pay careful attention to the light reflection coming off the mirror.
5. Now point the flashlight beam on the surface of the water in the baking dish.
6. Once again tell students to pay careful attention to the light reflection coming off the mirror.
7. Repeat pointing the flashlight beam on both surfaces a few times.
8. Now tell students it's time for the quiz.

9. Ask students why they think the light reflections were different? (Any answers that refer to the characteristics of the reflective surfaces being smooth and rough are acceptable).

10. Explain to students that:

    The light reflection from a smooth, mirror-like surface is called a specular reflection.

    When light rays are reflected at many different angles and the image is disrupted, it is called a diffuse reflection.

11. You can end the activity here or instruct students to illustrate the demonstration in a science journal, as homework or as an in-class assignment.

12. Write the words “specular reflection” and “diffuse reflection” on the board.

13. Tell students to use these terms when labeling their illustrations.

Heat Waves?-Demonstration

Description:
Students observe how heat bends light and learn how mirages of water appear on a hot road.

Time: (1) 15 minute session

Materials Needed:

- A flame produced by a candle
- flashlight
- white backdrop (wall or posterboard)

Procedure:

1. Ask students if they have ever seen a mirage or illusion of water on a street or road when it is really hot out?
2. Tell students they are going to uncover the mystery of this illusion.
3. Place the heat source (candle) on a table with the white backdrop behind it.
4. Light the candle.
5. Now turn off the lights and shine a flashlight over the heat source towards the white backdrop. (You should see waves on the white back drop)
6. Ask students to make guesses as to why the light shimmers.
7. Explain to students that:

    It has to do with the speed of light. If you look up the speed of light, you will find that it is 186,000 miles per second. If you read carefully, you will see that it says that this is the speed of light in a vacuum. It travels at different speeds when it is traveling through other things, such as air, water or glass.

    What does all of this have to do with the heat source? As the air heats it expands. This makes the air less dense and so it begins to rise upwards. As light moves from the more dense, room temperature air to the less dense, hot air, it changes speed and is bent, just as it would be by a lens. The rising air does not form a smooth, bent surface as it rises. Instead, the hot air swirls as it rises. As its surface ripples and changes, the way that it bends the light also changes. This causes the light passing through the hot air to waver and shimmer.

    The same thing can often be seen in the hot air rising from a road in the summer. This bending of the light by the hot air can make is seem that there is a pool of water on the road. As your car gets closer, the pool of "water' seems to disappear. It was not really water, but a mirage caused by the bending of light.

Adapted from Experiment of the Week #237, Robert Krampf's Science Education Company www.krampf.com

Shadows and Light Demonstration

Description:
Students discover how the brain perceives color by observing colored shadows produced with different colored lights.

They also discover how primary colors of light can create white light.

Time: (1) 30 minute session

Materials Needed:

- dark room
- 40 watt white light and socket (a shade-less lamp will work)
- 40 watt red light and socket (You can buy a cheap, colored lights at most hardware stores)
- 40 watt green light and socket
- 40 watt blue light and socket
- white wall or large sheet of white paper

Procedure:

1. You can start this demonstration in silence, which should intrigue students.
2. First, shine the white light onto the white wall.
3. Put your hand in between the light and the wall and create shadows.
4. Turn off the white light and turn on the red one. Make more shadows.
5. Now it gets interesting. With the two lights about a foot apart, turn on both the white and red lights.
6. Before you put your hand in front of the lights to make shadows ask students:

"What color do you think the shadows will be?" (students respond)

7. Now make shadows with your hand.
8. You should see two shadows now, one from each light. One shadow will be red. The other shadow is...green? Where did the green come from?
9. Explain to students that:

   Well, the shadow is not really green. It looks green, but that is a result of the red light surrounding it. The color sensitive cells in your eye get "tired" of seeing the red and when you look away, they react more to the other colors than to the red, leaving a green image.

10. Now try the green light. (the green light will produce shadows that are red)
11. Tell students they are no going to discover the mystery of white light.
12. Point the three colored lights, red, green, blue, on one spot. (The combined lights should form white light).
13. Ask students what they see. (white light)
14. Ask students what they have discovered. (White light can be made up of red, green and blue light)

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Adapted from Experiment of the Week #219, Robert Krampf's Science Education Company www.krampf.com

Making Waves- Demonstration

Description:
Two student volunteers make waves with a long rope to simulate light waves. Proton energy as it relates to color, frequency and wavelengths are explained.

Time: (1) 45 minute session

Materials Needed:

- Long rope (the longer the better, but not less than six feet)
- Image of visible light spectrum or rainbow (red,orange,yellow,green,blue,indigo,violet)
- Blackboard or other drawing surface

(students)

- Colored markers or pencils (red,orange,yellow,green,blue,indigo,violet)
- Science journal, notebook or unlined paper

Procedure:

1. Display image of spectrum or rainbow.
2. Ask for two student volunteers.
3. Give each student volunteer an end of the rope and have them spread apart so the rope is extended, but still loose. Tell them to wait for your instructions.
4. Tell students they are going to see what a long rope has to do with the colors in the rainbow or spectrum.
5. Explain to students that:
    - Scientists believe light is created by photons.
    - Photons have different energy levels and produce different colors.
6. Instruct one of the student volunteers to move one end of the rope up and down slowly while the other students holds the other end tightly.
7. Explain to students that: Here we see low energy photons and the wave of light they produce.
8. Tell students to observe how big the waves are and how many are created.
9. Point to the color red on the rainbow or spectrum and tell students that this wave action represents the lowest energy on the spectrum, the color red.
10. Now instruct the student volunteer to move the rope up and down slightly faster.
11. Explain to students that:

As the photon energy increases another color is produced. This time orange.

12. Tell students to notice how big the waves are and how many are created.
13. Now that students get the idea of wave action as it relates to color, have the student volunteer gradually increase the speed of the wave action as you verbally call out the rest of the colors and point to the rainbow or spectrum:

    Yellow

    Green

Blue

Indigo

Violet (the rope waves should be at maximum speed now)

14. Okay, let's give these light wave makers a rest.

15. Draw a wave motion on the blackboard.

16. Explain to students that:

    - The size of the wave is called wavelength. (the length from wave crest to wave crest)
    - The amount of waves created is called frequency
    - Scientists use a piece of equipment called a spectrometer to measure wavelength and frequency of light waves

17. Tell students they are now going to diagram and illustrate light waves.

18. Tell students you are going to repeat the light wave action with the rope and that they should carefully observe how the wavelength and frequency changes as the colors change.

19. Instruct the student volunteers to start making slow waves and increase speed as you call out the colors.

Red

Orange

Yellow

Green

Blue

Indigo

Violet

20. Now instruct students to use their colored markers or pencils to make light waves that represent the different colors. (wavelength should decrease and frequency increase as students move through the spectrum)

Magnifying Glass

Description:
In this short, simple activity, students observe the changes in magnification when light is bent through water. Provocative questions encourage students to think about the characteristics of light in different settings.

Time: (1) 25 minute session

Materials Needed:
(per student group)
- a tall, clear drinking glass
- your finger, a spoon,
- container of water, enough to fill glass

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Preparation:

1. Write down and display the following questions to ponder:
- Would a camera lens on Earth (in air) work the same in space?
- If you wear eye glasses, do you think they would work well if you were underwater?
- Do your eyes work as well underwater as in air?
- What would you see if you were in a room filled with water and you stuck your finger into a glass of air?

Procedure:

1. Introduce the questions to ponder either the day before or before you begin this activity to help students start thinking about the concepts.
2. Distribute materials to student groups.
3. Have students place the empty glass where everyone in the group can see it.
4. Instruct one student in each group to stick their finger in the empty glass.
5. Tell students to pay careful attention to how the finger looks.
6. Now have students fill the glass with water.
7. Instruct one student in each group to stick their finger in the water-filled glass.
8. Ask students about what they observe. (fingers should look bigger)
9. Now tell students to place the spoon in the water-filled glass.
10. Ask students to ponder this question:

Why does an object that is about half as wide as the glass seem to fill it? (students respond)

11. Explain to students that:

    The glass of water acts as a lens to magnify objects inside. The thin layer of glass alone does not cause the magnification. You need the water for it to work. Without the water, light enters the glass and hits your finger. Some of the light is absorbed, and some is reflected, spreading outwards. Some of this light hits your eye and you see your finger.

    With water in the glass, things start the same. Light still reflects from your finger and spreads outwards. This time as the light moves from the water to the glass and then to the air, something happens. Its speed changes. Wait a minute! The speed of light is a constant, right?

12. Ask students is it possible for the speed of light to change?
13. Explain to students that:

    When we hear that light travels at 186,000 miles per second, that speed is for light in a vacuum or outer space. When it travels through other substances (air, water, glass, oil) it has different speeds. As it changes speed, if it is traveling perpendicular to the surface (straight through), nothing much happens. If the boundary is at an angle to the direction the light is traveling, the light is bent from its path.

14. Ask students to describe how the path and speed of light changes when it hits the glass. (the light hits a curved surface and slows down)
15. Explain to students that:

    If the boundary is curved, then the image is distorted. Depending on the shape of the boundary and the speed of light in each of the substances, the light waves can be spread apart or bent together. If they are spread outwards, the image looks bigger. If they are bent inwards, the image looks smaller.

Note: The Disappearing Glass Rod exhibit supports this activity and illustrates the refraction of light when passing through a boundary of differing optical densities.

Adapted from Experiment of the Week #306, Robert Krampf's Science Education Company www.krampf.com

Book List

Light

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