Investigation 8
Reflections on Reflection

Authors
Theron Blakeslee, David Bydlowski, Tom Green, Bill Welch, Tom Wessels

Subject
Physical Science

Grade Level
Grades 5-8 (middle school benchmarks)

Driving Question
How does light interact with different surfaces?

Abstract
Students explore reflections from mirrors and other shiny and non-shiny surfaces, using various light sources. They determine ways to measure reflectivity. Then each group creates its own researchable questions regarding the reflectivity of different materials. Each group carries out the investigation it designs and presents its methods and results to the class. Students discuss, and may do, additional inquiries as time allows.

Michigan Curriculum Framework Science Benchmarks
http://www.miclimb.net/content/main.html

Constructing New Scientific Knowledge Benchmarks:

I.1.M.1 Generate scientific questions about the world based on observation.
Key concepts: Scientific questions can be answered by gathering and analyzing evidence about the world.
Real-world contexts: Any in the sections on Using Scientific Knowledge.

I.1.M.2 Design and conduct scientific investigations.
Key concepts: The process of scientific investigations—test, fair test, hypothesis, theory, evidence, observations, measurements, data, conclusion. Forms for recording and reporting data—tables, graphs, journals. See C-I.1 m-3 (tools).
Real-world contexts: Any in the sections on Using Scientific Knowledge; also, recognizing differences between observations and inferences; recording observations and measurements of everyday phenomena.

I.1.M.3 Use tools and equipment appropriate to scientific investigations.
Tools: various data collection tools suitable for this level, including computers.
Real-world contexts: Any suggested in Using Scientific Knowledge benchmarks for which students would design and/or conduct investigations.

I.1.M.4 Use metric measurement devices to provide consistency in an investigation.

Key concepts: Documentation—laboratory instructions. Measurement units—milliliters, liters, millimeter, centimeter, meter, gram.
Measurement tools: Balancing devices, measuring tape, thermometer, graduated cylinder.
Real-world contexts: Conducting investigations, following or altering laboratory instructions for mixing chemicals.

I.1.M.6 Write and follow procedures in the form of step-by-step instructions, formulas, flow diagrams, and sketches.
Key Concepts: Purpose, procedure, observation, conclusion, data.
Real-world contexts: Listing or creating the directions for completing a task, reporting on investigations.

Reflecting on New Scientific Knowledge Benchmarks:
II.1.M.2 Describe limitations in personal knowledge.
Key concepts: recognizing degrees of confidence in ideas or knowledge from different sources, evaluating dates and sources of references.
Real-world contexts: Any in the sections on Using Scientific Knowledge.

II.1.M.3 Show how common themes of science, mathematics, and technology apply in real-world contexts.
Thematic ideas; Systems-subsystems, feedback models, mathematical constancy, scale, conservation, structure, function, adaptation.
Real-world contexts: Any in the sections on Using Scientific Knowledge.

Using Physical Science Knowledge Benchmarks:
Waves and Vibrations IV.4.M.4 Describe ways in which light interacts with matter.
Key concepts: Reflection, refraction, absorption, transmission, scattering, medium, lens. Transmission of light—transparent, translucent, opaque.
Real-world contexts: Objects that reflect or absorb light, including mirrors; media that transmit light such as clear and frosted glass, clear and cloudy water, clear and smoky air; objects that refract light, including lenses, prisms, and fiber optics; uses of lenses, such as the eye, cameras, telescope, microscope, magnifying lens, for magnification and light-gathering.

Big Idea
Light interacts with some materials by bouncing off of it. If it bounces off it in only one direction, the light has been reflected. If it bounces off it in many directions, the light has been scattered.

Prerequisites For Students
Students should know that light travels in a straight line and that reflections are light bouncing off of a surface (changing direction).

Estimated Time Needed
4 class periods

Background Information

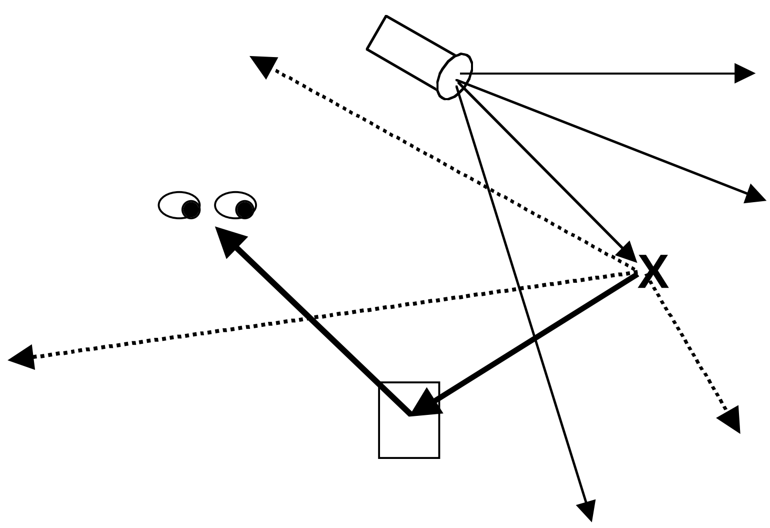
Mirrors and reflections are all around us. In spite of this, the principles that explain mirrors are often not understood. Some common misconceptions about mirrors include: a mirror reverses everything; the mirror image of an object is located on the surface of the mirror, and the image is like a picture or a flat surface; a mirror works by the image going from an object to the mirror surface, then the observer sees the image on the mirror surface, or the image reflects off the mirror and goes into the observer's eyes; light reflects from a shiny surface in an arbitrary manner; light is reflected from smooth surfaces but not from non-shiny surfaces.

Hopefully, by doing investigations with lights, mirrors, and less-reflective surfaces, students will begin to dispel some of these misconceptions.

Some basic principles follow: Light is a form of energy that can travel from a source to an object. Seeing an object requires that light travels from some light source to the object, and then travels from the object to the eye of the observer. Light travels in straight lines. Light reflects from a mirrored surface in a well-defined manner, such that the angle of reflection equals the angle of incidence. Light is scattered from a non-shiny surface; that is, incident light is reflected in all directions.

Students in this investigation will learn about regular reflection (light reflects off all surfaces which are extremely smooth and shiny at the same angle at which it hit the surface). Surfaces of metal, glass, and water are examples of these surfaces. Because of this interaction with light, these surfaces can be used as mirrors – we can see images in them. When you look into such a "mirror surface," your image appears to be an equal distance behind the surface as you are in front (if the mirror is flat rather than curved).

Most objects we encounter are diffusely reflecting objects—wood, paper, cement, clothing, skin, etc. Consider a piece of paper that is illuminated by light. When you look at the paper, light diffusely reflecting from each point can enter your eye, enabling you to see the paper at its actual position. Instead of seeing any image, you just see the illuminated paper. The fact that most objects we encounter in our everyday experience are diffusely reflecting allows us to see them.



This drawing shows light being **emitted** by a flashlight, and traveling out in all directions (the solid lines). Some of the light strikes an object (the X) which **scatters** light in all directions (the dotted lines). Some of that scattered light strikes a mirror, which **reflects** the light only in the same direction that it struck the mirror (the dark solid lines). This reflected light enters the observer's eyes, allowing her to see the object.

As an illustration of regular and diffuse reflection, place a light bulb near a sheet of paper and a plane (flat) mirror. If the paper and the mirror both reflect light, why do they appear different? Why doesn't the paper act like the mirror does?

The answer has to do with the way the light reflects from the paper and the mirror; the light scatters off the paper, but reflects regularly from the mirror. The eye sees the light that reflects in all directions from the piece of paper. Therefore, since light from the bulb scatters off of every point on the surface of the paper, the eye will see the whole paper. However, light going from a bulb to a mirror reflects regularly, at the angle of incidence. The reflecting light then enters the eye as if its point of origin were on the other side of the mirror. The observer then sees the image of the light bulb, and our brain interprets the correct position of the bulb (off to one side, not behind the mirror).

Scattering happens because surfaces like paper and wood are not nearly as flat as a mirror – not on the microscopic level. If you looked at a magnified view of paper or wood, you would see peaks and valleys, crevices and ridges made from the fibers. When light strikes these surfaces, it bounces off the one ridge in a certain direction, off the side of a valley in another direction, and so forth, scattering light in all directions. Crinkled aluminum foil, if smoothed, could produce a partial reflection and partial scattering.

This lesson gives each student group a chance to develop a question on which to do an investigation. All student groups can use the format given to develop and test their hypotheses in a scientific manner. However, not every question is one that should or can be investigated in an experimental manner. Some questions can be answered through research in the library or on the internet. Questions that require investigations are ones that require data from observations or experiments, from which a conclusion can be drawn.

Teacher Page 8-1 gives a sample of how a student group might fill out Student Page 8-1, involving investigation design. Teacher Page 8-2 gives an example of a Research Methods page. These are meant to be used as examples, not as instructions for any group's investigation.

Materials List

For each student group

Newsprint
Marker
Student Page 8-1 (have extra copies on hand)
Student Page 8-2

For the class

Wall mirror
Small mirrors
Flashlights
Maglite flashlights
Aluminum foil
Plastic wrap
Cloth
Wood blocks
Paper
Plexiglass
Colored glass
Other materials students want to use
Lamps
Laser pointers (optional)

Advance Preparation

None required.

Procedure

Part 1: Student Exploration

1. Let students try several things with the mirrors, flashlights, lamps, and other materials you have. (If you have a laser pointer, give strict safety rules for its use: No looking at the light source or shining it near peoples' faces.) Have students record their observations.

2. Turn off the lights and have students observe where a flashlight's beam of light shows up when it reflects off a mirror as the mirror is moved from place to place. Let them try adding a second and third mirror into the path of the light.

3. Have students look at the reflections of other students in mirrors. Have one student stand several feet to one side of a wall mirror and a second student stand some distance away in the other direction, moving until they see their friend's reflection. Ask them to try to explain why they can see the reflection at that place in the room and not at other places. These are just hypotheses at this point, not full explanations. This is not the time to tell students how reflection works.

   Place another student somewhere else in the room, and have others predict where they will have to stand in order to see the second student in the mirror. Let them make predictions with the mirror covered by a sheet, then uncover the mirror and check their predictions.

4. Place different types of materials on the wall to see if students can see reflections in them. You may try things such as aluminum foil (smooth and crinkled), plastic wrap, clear glass or plexiglass, a window, colored glass, cloth, wood, paper, and other materials students want to try. Light them in different ways.

5. Let them speculate and pose questions about why some materials seem reflective while others don't.

6. Let students reflect a laser pointer (after being given appropriate safety precautions) and a Maglite off various types of materials. Have them develop means of quantifying the reflections they produce off various materials.

Part 2: Question for Investigation

1. Divide students into groups of four or five.

2. Help each student group develop a researchable question about how different materials reflect light. A testable question is one that will require them to collect data. These criteria can help judge possible questions:
   - Does the question involve how something changes when acted on by something else?
   - Does finding the answer involve some scientific process?
   - Is measurable data needed to answer the question?
   - Does finding the answer involve some comparison?

Several possible student questions are:

- What happens to the size of laser light when it is shined on different materials?
- When can transparent materials also be reflective?
- Where does the light source from a Maglite appear be when the Maglite is shined on different surfaces?
- How can we predict where to stand in order to see the reflection from someone standing to the side of a mirror?
- How far back from a mirror do we have to stand in order to see our entire body (or how big does a mirror have to be in order to see our entire body?)

3. Have each group write down their researchable question on Student Page 8-1, Investigation Design.

4. Then have each group discuss and record what they already know, as a group, about reflection, on Student Page 8-1.

Part 3: Method for Gathering Data

1. Each group should spend 10 to 20 minutes figuring out how they can accurately and reliably gather the data they need. To do this, they should gather the materials they think they will need, then allow all group members to make suggestions about how to set up the materials and make measurements. At this stage of development, group members should write down all suggestions, and not criticize any – this is the process of brainstorming, which brings forward as many good ideas as possible.

   Circulate among the groups while they are brainstorming and facilitate their discussions as needed. Ask questions such as "What if you tried this…?"

2. After several possible approaches are listed, ask each group to decide on the method they want to use. Have them write a brief description of the method on Student Page 8-1, and the type of data they expect to collect. For example, if they want to investigate how a flashlight reflects off of glass, they might decide to shine the flashlight at various angles off of the glass, and see what kind of reflection it has, if any. They would need to record the angles at which they shined the light on the glass, and the amount of reflection, if any. Teacher Page 8-1 shows an example.

Part 4: Prediction/Hypothesis

1. After groups develop their method, have them make a prediction or hypothesis about the outcome of applying their method to the question. You may need to model one for the entire class. It should be something like: **If** we point the flashlight at the glass from different angles, **then** the light will reflect only at certain angles. Each group will have a different prediction, depending on the question they have chosen to investigate.

2. Have students complete the Investigation Design student pages.

Part 5: Research Details

1. Using a page titled "Research Methods," have students write a detailed plan for conducting their investigation. The plan should list every step they intend to take. (A sample Research Methods page is attached, Teacher Page 8-2.) They will need sufficient time to think about all the details of collecting the data. The methods they develop should allow them to find out whether their hypothesis or prediction is correct.

   They should develop a table or chart for recording the kind of data they plan to collect.

2. Have groups hand in their Investigation Design (Student Page 8-1) and Research Methods for your review. Check each group's design to make sure it includes a hypothesis and that there is a clear method for recording data. Give guidance as you review the materials, but try not to dictate specific changes. This is best done by asking critical questions such as, "How will you measure that?," and "What things will you keep the same?" Then groups can come up with changes that answer your questions and critiques.

3. Return the Research Methods with your comments and let groups re-design or alter their research methods as needed.

Part 6: Data Collection

1. Have students do their investigations and collect their data on the data collection forms they have designed.

2. Assist each group as needed. If changes must be made to the research methods, each group must record the changes in their procedure.

Part 7: Data Analysis, Use and Communication of Results

1. After groups collect their data, they need to analyze it in order to draw conclusions about whether their hypothesis is supported by the data – and therefore what the answer to their question is. Ask groups to discuss their data and look for patterns. Does their data support their hypothesis? What conclusions can they draw?

2. Have students complete questions 1-4 on Student Page 8-2, the Conclusions page. Question 4 asks them to compare their work to other groups in the class who have tested similar hypotheses. Facilitate the exchange of data and conclusions between similar groups.

3. Hold a class discussion to *use* the knowledge they have gained from the investigations to think about how light is reflected from surfaces. If student groups conducted a variety of experiments, some having to do with the angles at which light reflects off mirrored surfaces, then you should begin the discussion with those investigations, establishing how light is reflected at the same angle at which it struck the surface (from a mirror).

   Extend this discussion into how we see images in mirrors – from light reflecting from each part of the image (e.g. our body) to our eyes. See the background information if needed for this discussion.

Then continue the discussion by asking about why light doesn't reflect in the same way off of wood or paper or other non-reflective objects. You might want to use props in this discussion, such as paper, wood, crinkled aluminum foil, flattened aluminum foil and a mirror. Ask students how each surface is different, in terms of how light would bounce off it. They should see that light bounces in a certain angle from all flat surfaces, but surfaces like crinkled aluminum foil are simply composed of many flat surfaces pointed in different directions.

4. Ask students to complete Student Page 8-3, Thinking About the Data. These questions should be answered individually, after the discussion, so all students have a chance to think about them and develop answers.

5. Have students finish the Conclusions page based on the discussion. The fifth question used in the conclusion is "How can you explain what you found out?" Students should be able to answer this after the discussion in #3 and their writing in #4. The last question asks students to reflect on their investigation and suggest ways they might improve it. Before writing this part of the conclusion, allow students to discuss the last question in their groups.

6. Have each group present its question, hypothesis, research methods, graphic representation of data, and conclusion to the class. Every group member should have a part in the presentation. Presentations should include these parts (write them on the board):
   1. The group's question
   2. The full hypothesis
   3. The research methods
   4. The data, presented as graphs, charts, or drawings
   5. The conclusion
   6. Participation by each group member

   You may ask each group questions such as:
   - Did your data support your hypothesis?
   - What conclusions can you draw from your data?
   - What evidence supports your hypothesis?
   - Were there any errors in your research design or data collection?

7. Have students turn in all Student Pages, the Research Methods, and any data analysis for assessment purposes. If you wish, you may have groups put these together on poster board as a display that can be set up where others in the school can see it.

Part 8: Guided Questions for Reflection

1. Lead a class discussion on the ways they conducted their investigations and what they learned from them. You may ask whole class questions such as:
   - Could this method of investigation work for other areas of interest?

- Could this method work outside of science?
- What did you learn about answering scientific questions?

You may also wish to ask specific questions about the topic that extend beyond their investigations, such as:

- How does light interact with different kinds of matter?
- Is anything a non-reflective surface?
- When are reflections useful?
- How does light reflect from a calm pond versus one with many waves? How is this like how light reflects from a piece of smooth aluminum foil and a crumpled piece of aluminum foil?
- When are reflections useful to us? When can they be harmful?

Part 9: Student questions for additional inquiry

1. Ask the class:
   - Are there questions the investigations didn't answer? What are they?
   - How could these questions be answered?

2. If you are able, do some of these subsequent investigations with students.

Assessment

Group assessment can be made by ranking proficiency in each of the parts of the final presentation: the hypothesis, the Investigation Design page, the step-by-step Research Methods, the graphic presentation of the data collected, answers to the questions on "Thinking About the Data," the conclusion, and, finally, the participation of all members.

Individual assessments can be done by interviewing individual students about their group's project and assessing their understanding of what the group did and why it was done.

Names____

Investigation Design

1. What is our question?

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2. What do we already know about reflection?

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3. What will we do to gather data?

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4. What data will we collect?

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5. What is our hypothesis?

6. The things we keep the same on purpose are:

Names____

Conclusion

Answer these questions in your conclusion:

1. What was the purpose of the investigation?
2. What did you find out?
3. Was the hypothesis supported by the data?
4. How do your findings compare with those of other researchers?
5. How can you explain what you found out?
6. What else would you like to do with this investigation, and how would you make it better?

Name______________________________

Thinking About the Data

Answer all of these questions in your conclusion:

1. How can you predict where a beam of light will reflect off a mirror?

2. How can you see a piece of white paper if it doesn't reflect light like a mirror?

3. Why does light scatter off a piece of paper?

Names (Sample Student Responses)

Investigation Design

1. What is our question?
   Is there a way we can get a flashlight to be reflected off a piece of glass?

2. What do we already know? – about reflection
   Sometimes we see our reflection off of glass at night, when we are inside looking out. Light can be reflected off of extremely flat or shiny surfaces. The angle that it hits the surface is the same as the angle that it bounces off. (NOTE: This second statement would not necessarily be known by all groups. It might even be a question for investigation – where the reflected light goes when the flashlight is shined from different angles.)

3. What will we do? – to see a reflection off of glass?
   We will point a flashlight at glass from different angles and observe whether there are any reflections.

4. What data will we collect?
   We will record the angle at which the light strikes the glass, and where the reflection goes.

5. What is our hypothesis?
   If we point the flashlight at the glass from different angles, then the light will reflect only at certain angles. (NOTE: This hypothesis does not specify which angles. Students may actually take a guess at which angles will produce reflections.)

6. The things we will keep the same on purpose are:
   We will always use the same flashlight and the same piece of glass. We will hold the flashlight the same distance away from the glass.

Names (Sample Student Responses)

Research Methods

1. Find an appropriate window for the piece of glass, and a flashlight that is bright enough to see any reflection in the day time.
2. Tape a string 1 meter long to the middle of the glass. Hold the flashlight at the end of the string.
3. Place a piece of white poster board at right angles to the glass on the other side from where we will shine the flashlight.
4. Using a protractor against the window and along the string, place the flashlight at 10, 20, 30, 40, 50, 60, 70, 80 and 90 degrees. Observe whether there is a reflection and if so, where it is (using the protractor).
5. Record the data in a table like this:

Angle of flashlight	Angle of reflection	Brightness of reflection
10°		
20°		
30°		
40°		
50°		
60°		
70°		
80°		
90°		