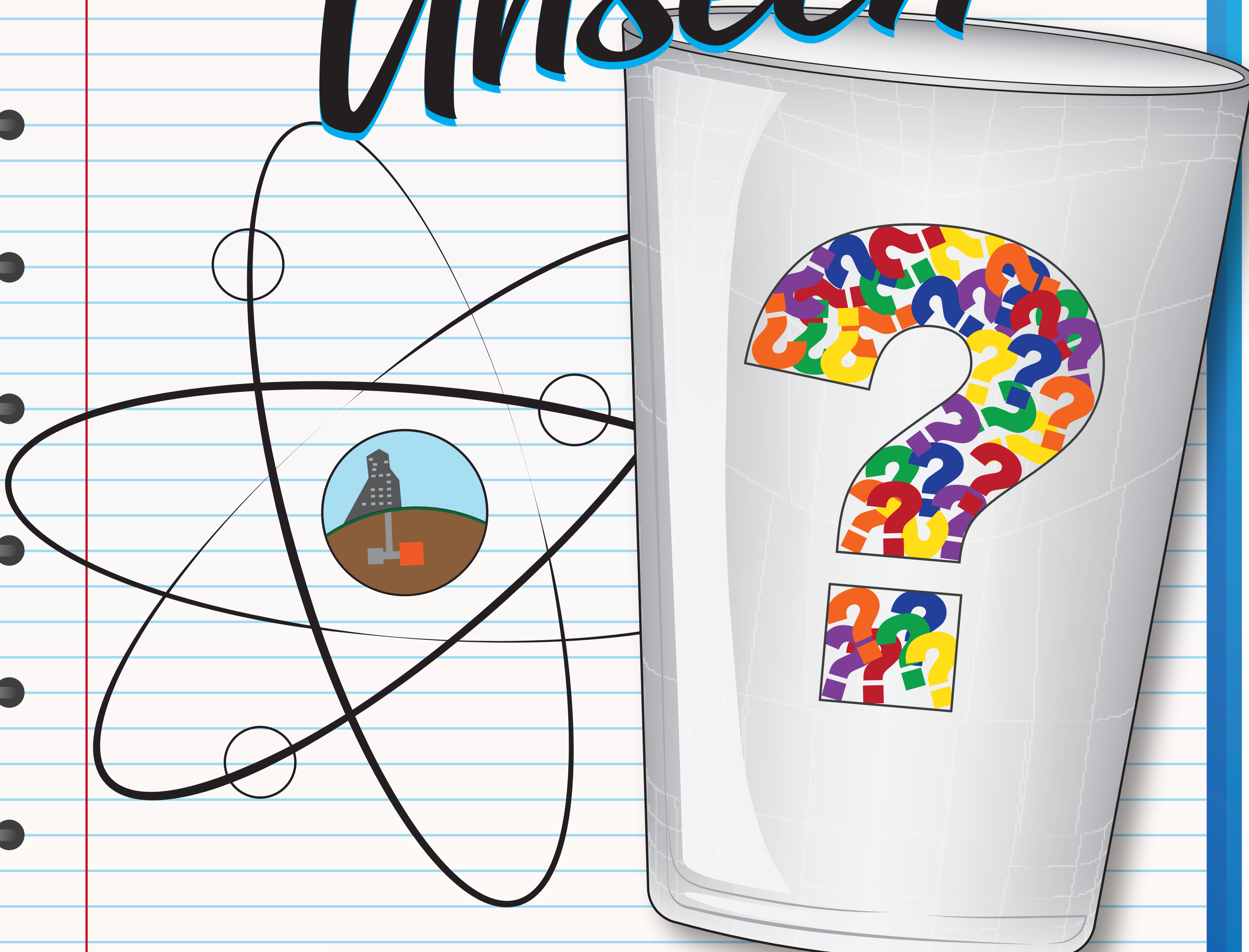
Exploring the Unseen



Education and Outreach

3 - 5

Curriculum Unit

Exploring the Unseen

"Using Indirect Evidence"

Science Focus: Constructing an Evidence-Based Explanation

Lesson #	Lesson Title	Suggested Time
1	Introducing the Unit Paper Towel Challenge	55 minutes
2	Rutherford Scattering Atomic Target Practice	55 minutes
3	Testing Mental Models Model Students	55 minutes
4	Black Boxes It's a Mystery	55 minutes
5 *	Condensation Conundrum No Sweat!	55 minutes
6 *	Condensation Continued What if…? Exploring Testable Questions	55 minutes
7	Pulling it All Together Tie to SURF Science (Dark Matter)	55 minutes
8	Post Assessment SURF Information	30-55 minutes

*Explorations in lessons 5 and 6 will not work if the humidity is too low.

Exploring the Unseen- Grades 3-5 (Physical Science)

Students gather and use indirect evidence to reason about things too small to see, too remote to reach, and otherwise difficult to detect. Is an empty cup truly empty? How do we know? How do we know that atoms have even smaller subcomponents? Connections are drawn to the Sanford Underground Research Facility's world-leading search for a mysterious substance called dark matter, which, to date, is only thought to exist by virtue of indirect evidence.

Exploring the Unseen

Using Indirect Evidence

Scientists, young and old, share a deep-seated curiosity about our world and the surrounding universe. Often we can look at, touch, or use one of our other senses to learn about an object or phenomenon. From such *direct observations*, we obtain evidence, *direct evidence*, about the subject of interest. Sometimes, however, objects or phenomena are too small, too large, too far away, or otherwise impossible to detect directly. So how do we as scientists study things that cannot be seen with the naked eye - or heard or smelled or touched? In many cases we do so through *indirect evidence*.

Indirect evidence is "detectable" information that can be pieced together to reason about that which cannot be sensed directly. Sometimes we can use tools, like microscopes or telescopes, to extend our senses. Other times we set about devising clever, creative ways to gather indirect evidence and use it to make inferences about what we seek to understand.

Scientists develop and use models to fit pieces of indirect evidence together. As new evidence is obtained, the model may be affirmed - or it may need to be refined or even discarded. Models can be physical, computational, or mental representations. They help to communicate our thinking. They can be used to solve problems, make predictions, and generate explanations.

Throughout this unit, students use both direct evidence (observable) and indirect evidence (from which they need to make inferences) to reason and to develop models about objects and phenomena they cannot see. This unit focuses heavily on "Science and Engineering Practices" as described by the National Research Council in *A Framework for K-12 Science Education* (2011).

Students explore properties of air, including its ability to displace water. Air can easily be overlooked as "nothing" or as "empty space," but its existence and its properties can also be reasoned about quite readily by way of indirect evidence.

Atoms themselves, the building block of matter, were investigated by way of indirect evidence long before microscopes were powerful enough to make direct observations at the atomic scale. By rolling marbles at a hidden target, students make inferences about the properties of that hidden target. This process of gathering indirect evidence mirrors the way scientists were able to explore atomic structure over a hundred years ago.

Students explore water vapor, an invisible component of air, by considering condensation. Students see the formation of water droplets on a cold surface and make inferences about where the water came from. They design their own controlled condensation experiment by changing one of the variables, and they come to understand that something as simple as a cold surface can serve as a water vapor detector, a scientific instrument that provides indirect evidence about the presence and quantity of water vapor in the air.

The unit concludes with a connection to exciting research underway at the Sanford Underground Research Facility (SURF). Scientists at SURF are feverishly trying to make the world's first *direct* detection of "Dark Matter." Dark matter is called "dark" because it doesn't reflect or emit light. It cannot be seen and has never been detected directly by any scientific instrument. The very notion that dark matter exists is based entirely upon its observed effects on other things. This is a mystery that, to date, is understood solely by virtue of indirect evidence.

One of the types of indirect evidence that suggests the existence of dark matter involves the bending of light as it travels through the universe. Light emitted by distant stars is sometimes bent on its way to Earth – as if it were passing near a heavy celestial object, like a planet, but without any object in sight. A concentration of dark matter in that location could be the cause of this bending of light. Students explore an elegant analog to this phenomenon within the classroom, by looking at a penny at the bottom of a container of water. They develop a model about how light bends as it passes from the penny to their eyes, crossing the boundary between water and air. The presence of water in the container affects the way the light travels - similar to the way that the presence of dark matter in our universe is thought to affect starlight.

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Standards Addressed in the Unit

3-PS2-1 Plan and carry out an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

4-PS4-2 Develop a model to describe how light reflecting from objects and entering the eye allows objects to be seen.

5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen.

In addition to standards, Science and Engineering Practices (SEP) play an important role in the science classroom. The focus of this unit is constructing an evidence-based explanation. The majority of lessons in this unit focus on science skills and practices.

- Ask questions (SEP 1) and predict outcomes
- Make observations (direct and indirect)
- Develop and use a model (SEP 2)
- Plan and carry out an investigation (SEP 3)
- Analyze and interpret data (SEP 4)
- Use evidence to construct an explanation (SEP 6)
- Engage in argument from evidence (SEP 7)
- Obtain, evaluate, and communicate information (SEP 8)

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science)
   Designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

***A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*.** (NRC, 2012)

Crosscutting Concepts

1 Patterns

2 Cause and Effect:
Mechanism and explanation

3 Scale, proportion, and quantity

4 Systems and system model

5 Energy and matter:
Flows, cycles, and conservation

6 Structure and function

7 Stability and change

***A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. (NRC, 2012)**

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Materials List

- **Teacher-Provided**

Lesson	Materials Needed
1	➢ Materials to create science notebooks • Transparent cup • Tub for water ➢ Paper towels • Paper Towel Challenge handouts • Ping Pong Ball Challenge handouts (alternate) • Ping pong ball (alternate)
2	• Tennis ball • Large wedge (wood) • Rutherford boards w/ blocks of various shapes • Marbles *must be able to roll freely under board ➢ White paper ➢ Rulers* (optional)
3	➢ 1 stick string cheese ➢ Lighter (preferred) or matches • 1 slivered almond • 1 coffee stirrer or an extra-long wooden pick • 1 set of Inference cards per group of 4 students • Inference/Evidence Chart-1 per student
4	• 1 mystery gift, wrapped in decorative paper • Class set of mystery boxes
5	• Clean, empty can without label (1 per group) ➢ Pitcher for ice water ➢ Paper towels ➢ Magnifying glasses (optional) • *Planning an Investigation* handout • *Design Your Own Experiment* handout

6	• Clean, empty can without label (1 per group) ➢ Paper towels • Salt • Food coloring • Tall glass • Insulated plastic tumbler • Zip top bags • Thermometer ➢ Magnifying glasses (optional)
7	• Compact mirror • Flashlight • Transparent cup • Straw ➢ Water • Plastic container • Penny • Transparent Tape ➢ Permanent marker • Meter tape ➢ Ruler ➢ Paper to wrap container • Large colored solo cup
8	• Post-assessment handouts

Adjusting Modules to Accommodate Your Classroom Needs

Timing

The education team at Sanford Underground Research Facility (SURF) has done its best to develop curriculum modules that are flexible and incorporate both facilitator and student supports. As you explore this module with your students, please keep in mind that these curriculum modules are grade banded. If your students are at the lower end of the grade band, or if they come to you with limited experiences in science, you should fully expect the module to take more time than designated in the facilitator's guide. This is especially true if you teach very young students.

As an effective educator, you will know how to adjust the timing of these lessons to best fit your classroom and students. Please feel free to break any of the lessons into shorter segments, over multiple days, to accommodate the learners in your classroom.

Follow-up/Practice

Lessons in this unit include 'Follow-up/Practice' sections. These are useful (optional) resources proposed to enrich classroom practices for diverse learners. These resources are not included in the time designations of the unit; if you feel your students will benefit by pursuing these resources, please plan for additional time.

Design Principles

Effective educators alter, adjust, and change their instruction depending on who is in the classroom and the extent to which those students are succeeding. Frequently, educators will augment curriculum with additions of instructional strategies. However, please keep in mind that best practices in science education have shifted from merely *learning about* to *figuring out.* These units are designed to provide opportunities for students to figure out phenomena and design solutions to problems.

This emphasis on *figuring out* represents a revolution in how we teach science at all grade levels. In their learning, students must use all three dimensions of the science standards—crosscutting concepts (CCCs), disciplinary core ideas (DCIs), and science and engineering practices (SEPs)—in an integrated fashion in order to make sense of phenomena or design solutions to problems.

Classrooms incorporating three-dimensional learning will have students build models, design investigations, share ideas, develop explanations, and argue using evidence. All of which allow students to develop important 21st century skills such as problem solving, critical thinking, communication, collaboration, and self-management. Three-dimensional learning also helps students apply new knowledge to other situations. Every student will benefit from this instructional approach.

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Important Note	
Science Notebooks Anchoring Event	**You may wish to have students set up their Science Notebooks prior to the first lesson.** As children develop and refine their understanding of science concepts, it is helpful for them to reflect on and record what they have learned. A science notebook provides them with a record of their questions, ideas, experiences, and evidence. The science notebook can also be used by the teacher to assess the development of student understanding. Science notebooks may be a printed booklet prepared by the teacher, or a bound notebook. Science notebook support material can be found in the print masters. The anchoring event (paper towel challenge) is designed to provide students with a puzzling and engaging phenomenon for which they can come to a deeper understanding over the course of the unit. Do not attempt to explain this phenomenon to students. Allow them to wonder, reflect, and make sense of it on their own. In lesson 1, students are asked to explain, draw, and label a representation of what they experienced. They will repeat this throughout the unit. It is important that teachers remind students about expectations for the science notebooks and suggest ways they can improve entries. Science notebook checklists are provided in the print masters for easy reminders. This particular unit is rather curious in that it focuses on a variety of ways to observe the unseen, rather than one disciplinary core science idea. Thus, the goal for the post-assessment is for each student to develop more detailed, relevant science documentation in their notebook through words, pictures, and terminology.

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Lesson 1	Paper Towel Challenge
Overview Standard(s) & Objectives	**Overview** This lesson introduces how scientists study objects or phenomena that might be too small, too large, or too far away to study directly. Students are given the challenge of designing a procedure for keeping a paper towel in a cup dry when submerged in a tub of water. They come to reason about the existence of air in the cup, which is comprised of particles too small to see. **Alternate Exploration!** For students who have previously completed the paper towel challenge, you are encouraged to provide a similar challenge. Ask them to predict what will happen to a ping pong ball floating in the water container. Place the cup over the ping pong ball and push down. What do you think will happen to the ping pong ball. Why? **Building Toward** 5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen. Crosscutting Concept • Scale, Proportion, and Quantity -Natural objects exist from the very small to the immensely large. Science and Engineering Practice • Developing and Using Models- Use models to describe phenomena. **Objectives** Students • Consider how to study objects or phenomena that might be too small, too large, or too far away to study directly. • Design a procedure for keeping a paper towel in a cup dry when submerged in a tub of water. • Revise their design based on information from previous trials. • Make inferences about why the paper towel remained dry.
Background Information	When the cup with the paper towel is inverted, and the cup is submerged (and removed) while level, air pressure acts as a force pushing against the water. The air displaces the water, keeping the paper towel dry. (See Sample Student Drawing at end of lesson)

Exploring the Unseen

<table>
<tr><td>Materials</td><td>For each student:

Science notebook
Paper Towel Challenge Handout (to be completed after the Challenge)
Ping Pong Ball Challenge Handout (alternate)

Each group of 4 students needs:

Transparent cup
Paper towels (must be large enough to stay in the cup when inverted; otherwise, students should use a small piece of tape to hold the paper towel in place)
Tub of water (water level must be deeper than height of cup)

Note: If students request food coloring during the activity, see Lesson 6 supplies.</td></tr>
<tr><td>Prior Knowledge</td><td>It is helpful if students are familiar with the three states of matter: solid, liquid, gas.</td></tr>
<tr><td colspan="2" align="center">Launch (10 minutes)</td></tr>
<tr><td>Engagement and Communication of Student Expectations</td><td>Ask students to think about things that we know about but cannot see.
The facilitator should act as recorder. Keep a record of student ideas on chart paper or the whiteboard.
Students may come up with some of the following ideas: germs, gravity, Earth’s magnetic field, distant planets, even dinosaurs or unicorns.
If students are struggling to start the conversation, you might ask about the wind.

Can we see it with our eyes? Feel it? Hear it? (we observe its effects, or perhaps we need a special tool)
What is our evidence? (wind=rustling leaves, flapping flag, blowing things around, feel it, can use weather instruments to measure speed)

Discuss how researchers study objects (or phenomena) that might be too small, too large, or too far away to study directly.

Careful observation- what is happening (something changing or moving, ie food bubbling in a microwave)
Special tools- (microscopes, telescopes, compasses, or special detectors)
Clues left behind (shadows, tracks, fossil evidence, fur or feathers, etc)

Explain that science is the study of the world around us. During this unit, we will work as scientists in the classroom to learn by observing, describing, and experimenting to explore.</td></tr>
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Explore (35 minutes)

Procedure

Have a set of materials to show students. Tell them that their challenge is to find a way to submerge the paper towel in the tub without getting it wet. The ONLY materials they may use are a cup, a paper towel, and the tub of water. (The cup must touch the bottom of the container)

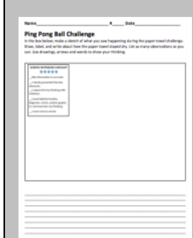
Answer any questions students may have, but do not lead them in solving the problem.

Group Work

1. Pass out science notebooks. Explain that scientists record their ideas, questions, and observations in a variety of ways. Students will use their notebooks to record their thinking throughout the unit. Demonstrate how to label and date each entry. (See *Science Notebook Template*)
2. Divide students into groups of four and provide each group with a set of materials. Review classroom norms for group work. You may wish to appoint a "*Materials Manager*" in each group to look after the supplies. (See *Cooperative Group Roles* sheet)
3. Allow students time to meet the challenge. As they work, circulate first to address any procedural questions and then to observe and to listen to what students are talking about. Ask probing questions (see below) to further their thinking.

   Tell students that they will eventually work independently to answer the question "***What did you notice while doing the paper towel challenge****?"* Encourage them to list as many observations as they can. These observations will be helpful in explaining why the paper towel stayed dry.
4. Provide time for students to share their ideas and confer with each other about why the paper towel stayed dry.

Alternate Exploration!



For students who have previously completed the paper towel challenge, you are encouraged to provide a similar challenge. Ask them to predict what will happen to a ping pong ball floating in the water container. Place the cup over the ping pong ball and push down. What will happen to the ping pong ball. Explain why?

- Does the ping pong ball stay at the top of the water? In the middle? Or go all the way to the bottom?
- What explains why this happens?

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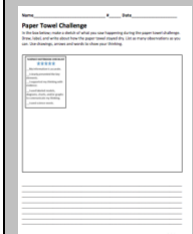

Individual Sense-Making

5. Distribute the *Paper Towel Challenge* Handout. *Have students write their name, number, and date on the document.* Call special attention to the checklist on the handout. This checklist will also be in their Science Notebooks and will play a vital role in documenting their progress.

   Students will work independently share observations and to explain ***why the paper towel stayed dry.*** They can use drawings, arrows, words, etc. to express their thinking about the components of their experiment. Students may use their Science Notebook as a reference.

Questions

Driving Questions

- What kept the paper towel dry? How do you know?
- If the cup is in the water, why doesn't the water get the paper towel wet?

Probing Questions

- What happened to the paper towel? Why do you think that happened?
- Did you notice anything unusual when you put the cup in the water?
- How could you change your procedure to get different results?
- How is that the same as, or different from, what you already tried?
- Does it matter how quickly or slowly you move the cup in or out? (When taking the cup out it is important to go slowly.)
- What did you try that didn't work? Why do you think it didn't work? Does that give you any ideas about what you could try next?
- If teams are quick to solve the challenge, ask: Is there anything you could try to prove what will *not* work?
- How does the cup feel when it's submerged? Will it stay at the bottom of the tub if you let go?
- What happens to the water level in the tub when the cup is submerged? What about when the cup comes back out?
- What would have made this challenge easier? Harder?
- What if the tub of water were deeper?
- What if you tilt the cup a little bit when it's submerged?
- Is there an amount you can tilt the cup that still allows for success? Is there an amount of tilting that's too much?

Teacher Tip: As you visit each group, it helps to start with an observation level question and then move toward asking about less observable features related to air and air pressure.

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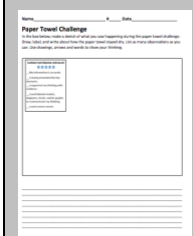
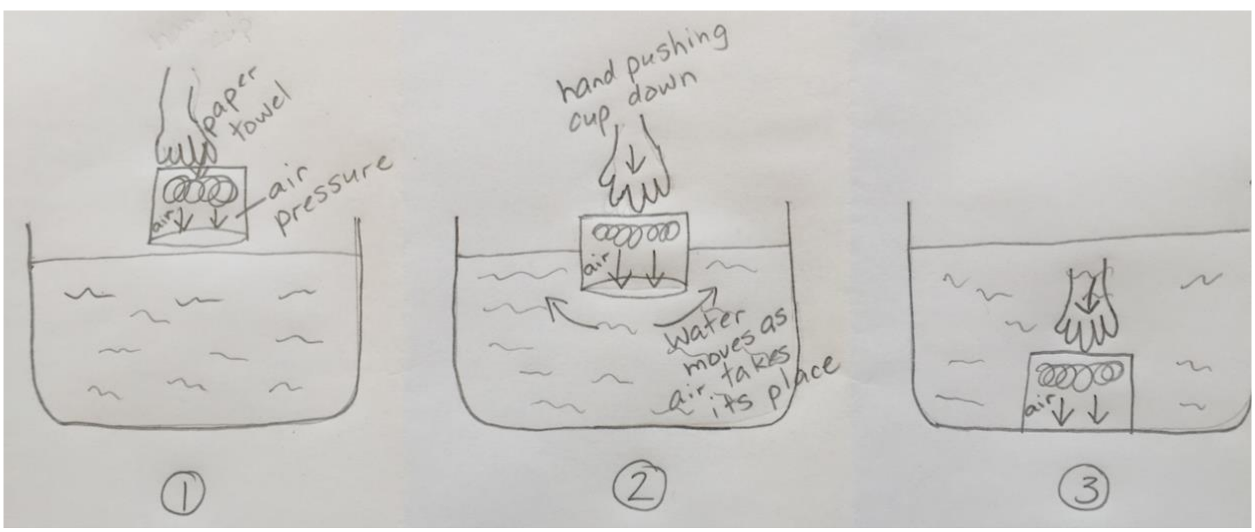
Summarize (10 minutes)	
Communicate	**Class Discussion** Once most (or all) groups have met the challenge, gather students together. Discuss the following: • What didn't work? Why? How did that help you move toward a solution that did work? Do you think that happens to other scientists or engineers? • What did work? What made it possible? • How did your thinking change as you tried different things? • Do you think there is anything between the paper towel and the water? (*Air*) • What evidence do you have that there is something in the cup between the paper towel and the water? Even though you can't see it, can you prove it is there? (*Air bubbles, feel pressure as pushing cup down, if let go of cup it would return to surface, if cup tilted slightly could see water line*) • How do you think other scientists study things they cannot see? What tools might they use? What evidence might they look for? Explain to students that, just because you can't see something it doesn't mean it isn't there. Gases (like air) are made from matter particles too small to see.
Terminology and Concepts to Solidify	**Evidence-** information that is acquired by observation or experimentation **Inference-** a conclusion reached based on evidence and reasoning **Matter**- anything that has mass and takes up space **Particle**- one of the very small parts of matter (for example, molecules and atoms) **Science-** the study of the world around us We can use what we observe to help gather evidence and reason about what we cannot see. Often, scientists try things (questions, materials, procedures, models) that do not work. Sometimes it is the things we cannot see that make the most interesting explorations. Scientists often take what people consider impossible or untestable and find a way to make it possible to study.
Connection to Big Ideas (Phenomena)	*Structure and properties of matter* Matter (air) is made of particles too small to be seen.
Follow Up/Practice	Present the paper towel challenge to friends and family and see if they can solve it.

	Introduce/Review the states of matter Kids' Discover Infographic (on USB drive) http://www.kidsdiscover.com/infographics/infographic-states-of-matter-for-kids/ Bill Nye's Phases of Matter Video (22 minutes 40 seconds) https://www.mycompassacademy.com/apps/video/watch.jsp?v=61919
Assessment 	*Paper Towel Challenge* Handout *Consistent and specific feedback will help students improve over the course of this unit.* As you examine students' work (using the checklist on the handout), make recommendations, ask clarifying questions, and provide suggestions that they can use to improve their entries/diagrams.

This is a sample of what you would hope to see at the end of the unit, once students have gone through each of the lessons.

Sample Student Drawing of the Paper Towel Challenge



Exploring the Unseen

Lesson 2	Atomic Target Practice
Overview Standard(s) & Objectives	**Overview** During this lesson students will discover, by indirect means, the size and shape of an unknown target concealed beneath a large board. By tracing the path the marble takes after striking the unknown target, from a variety of angles, it should be possible to estimate its general size and shape. **Building Toward** 3-PS2-1 Plan and carry out an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. Crosscutting Concept • Cause and Effect-Cause and effect relationships are routinely identified. Science and Engineering Practice • Planning and Carrying Out Investigations- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. 4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide. Crosscutting Concept • Energy and Matter-Energy can be transferred in various ways and between objects. Science and Engineering Practice • Asking Questions and Defining Problems- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. **Objectives** Students • Collect information by observing and measuring. • Identify patterns in a data set or experiment to draw conclusions. • Analyze and interpret information to construct reasonable explanations from direct and indirect evidence. • Use critical thinking skills to decide how a data set supports, or fails to support, a hypothesis. • Communicate valid conclusions.

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Background Information	Often, we can look at or touch an object to learn about it. Sometimes, however, objects are too small, too large, too far away, or too complex for us to learn about them this way. When this happens, we need to use indirect evidence techniques. Ernest Rutherford realized that atoms, which are the building blocks of nature, are much too small to be measured directly, and so he designed an experiment to measure their characteristics indirectly. He used a thin piece of gold foil at which he directed alpha particles, which were like very small cannon balls. Though he could not see the atoms in the gold foil, he knew that if he watched where the alpha particles went after hitting the gold foil, he could draw conclusions about the gold atoms. Alpha particles are very small, but they are heavy. They also travel quickly, and they have a positive electrical charge. When the alpha particles collide with a specially designed screen that Rutherford placed around the gold foil experiment, the screen would light up at the point of the collision. Rutherford conducted his famous experiment over a hundred years ago. At this time, scientists believed that the atom was composed of positively and negatively charged particles all mixed together. Therefore, Rutherford expected most of his positively charged alpha particles to pass right through the gold foil with little to no change in their trajectories. Though the majority of the alpha particles did pass through the gold foil unhindered, he was extremely surprised when some of the alpha particles bounced off the gold foil and came straight back! Rutherford is supposed to have stated: “It was quite the most incredible event that has ever happened to me in my life. It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you.” This experiment led Rutherford to conclude that an atom is actually mostly empty space with a small, dense, positively charged nucleus in its center. It was this dense, central nucleus that some of his alpha particles bounced off. Based on the number of alpha particles he shot at the gold foil, and the number of deflected and reflected particles, he was able to calculate a very good approximation for the size of the gold atom’s nucleus. Rutherford measured the diameter of the nucleus of a gold atom indirectly!
Materials	*For each student:* • Science notebook **Launch** • Tennis ball • Large wedge (wood) **Explore** • Rutherford boards w/ blocks of various shapes • Marbles (must be able to roll freely under board) • White paper to be placed on top of board • Rulers* (optional) • Sections of garden hose to use as “containment” of marbles during rolling (optional)

	*Ruler- marble roller: Since you will be rolling marbles under this model, it is recommended that the marbles roll straight. Rolling by hand often causes the marbles to roll in unexpected directions. Place the marble in the groove of an elevated ruler. Use the ruler's groove to guide the marble as it rolls. **Potential Block Shapes**  Place the Rutherford boards on a large table or on the floor, obstructing the shapes from the students' view. Place a piece of paper on top of each Rutherford board. **Beware:** your students may be tempted to peek.
Prior Knowledge	It is helpful if students have had some sort of experience with deflected objects. Students must be able to keep careful record of observations.
Launch (10 Minutes)	
Engagement and Communication of Student Expectations	Ask students to think about games they play that use balls. List a few on the board. In these games, does the ball always continue to move in the same direction? What things might cause the ball to change direction? Can the new direction be predicted? **Note:** This discussion will involve thinking about the change of direction through two lenses: Balanced and unbalanced forces, as well as changes in energy/direction when objects collide) Bounce a tennis ball off the floor and catch it. If the floor is level, the ball will bounce straight back to your hand. Then, place the wedge on floor where students can see it. Ask them if they can predict what will happen when the ball is bounced off the wedge. Have them draw/write their prediction in their science notebook. Ask students to share their predictions. Follow up with these ideas and ask them to explain their thoughts. Explain to students that today, they will be doing an activity that involves marbles. It is possible to predict the direction a marble will travel when it strikes a stationary object.

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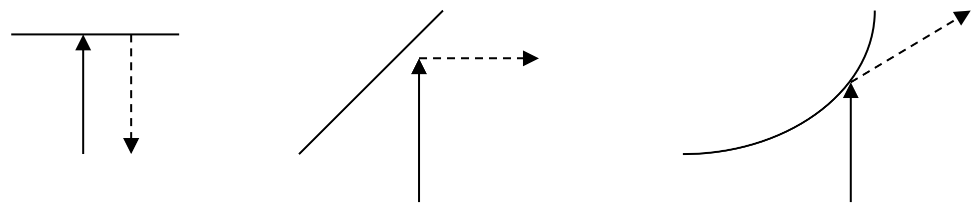
Have students (individually) draw a prediction to the following scenarios in their science notebooks.

> Assume that the marble strikes the following sides of a possible target. Sketch the path the marble might be expected to take in each case.

Note: Dotted lines are likely predictions. Do not share these with students until after the student discussion.



After students sketch predictions, have students share their thinking. Create a display of what the paths in *and* out might look like.

Student task

The purpose of today's activity is to determine the size and shape of an unknown target. The shape is hidden under a board. You will be given a marble to use as a tool to help determine its size and shape.

You will need to develop a method for recording the path the marble takes after striking the unknown target. You will need to collect data from a variety of angles. After collecting enough data, draw the general size and shape of the unknown target.

Before you begin

- What can be inferred if the marble rolls straight through?
- What will happen when the marble contacts a solid object?
- What can you learn from the motion of the marble after contact?

To do and notice

Students should roll marbles under the board to find out what's under it.

The two basic questions are:

- What's the shape of the target?
- What size is the target?

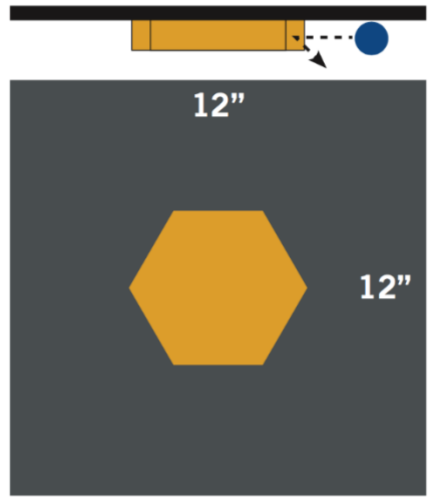
As students work, circulate first to address any procedural questions and then to listen to what students are talking about and to ask probing questions (see below) to further their thinking.

Explore (35 minutes)

Procedure

Rutherford Scattering

Side view and bottom view



1. Working in small groups, roll one of the marbles at the hidden target beneath the Rutherford board. One student draws the marble’s path in, and the deflected path out, on the piece of paper taped on the Rutherford board. (Group Role-Data Master) Map the paths of the marbles that do not deflect or deflect slightly, as well. Make sure you roll the marble fast enough so that it makes a clean shot in and out. (Students may wish to practice the rolling part before collecting data)
2. Repeat Step 1 as many times as needed to define the outline of the hidden shape. Make sure students roll the marble from each side of the board and from many points on each side of the board, making observations and tracing the rebound path for each marble roll.
3. After sketching the apparent path from all sides and angles, the general size and shape of the unknown target should emerge.
4. Form a working hypothesis concerning the structure of the unknown target. Based on this hypothesis, repeat as many ‘targeted’ marble rolls as necessary to confirm, or revise, the structure.
5. Once groups are satisfied that they know the shape of the object under the Rutherford board, they should draw the shape onto the piece of paper. (They might want to trace the shape from the paper with the outline formed by the collision paths).
6. Before looking at the actual target, show your teacher the shape you have drawn. Then look at the shape under the Rutherford board and discuss any parts of the shape you have drawn that do not match those of the target.

Teacher Tips

- Groups of three students seem to work well for this activity
- A section of garden hose fashioned into a circle can help contain wayward marbles.
- If the marble does not roll out from under the board, groups can carefully move the board to locate the marble. Data from that roll should not be recorded.

Exploring the Unseen

<table>
<tr><td>Questions</td><td>

Driving Questions

- How can we determine the characteristics of objects that we cannot see?
- How do scientists/we know about the natural world if we can't see all of it?

Probing Questions

- What details can you determine from the path of the marble?
- Does the data from one roll provide enough information to determine the shape of the hidden object? What about 2 rolls? How do you know when you have enough data? Have the class agree on a minimum number of trials. (Note: It will take at least 8-12 trials just to possibly get one of the easier shapes. More data will be beneficial.)
- Based on your data, can you trace the shape you think is under your board?
- Does everyone in your group agree on the shape?
- Why is it important to also record the misses (trials where the marble was not deflected) in this activity?
- Did you collect data from rolling the marble on each of the sides of the Rutherford board?
- How did your predicted shape of the target compare with the actual shape?

Teacher Tip

Let students know that scientists do not "guess" at the answers until someone tells them they are right. Scientists have to make sure they have collected enough data from multiple experiments using different variables before they announce their results. Imagine if you lost grant money, your job, or your reputation as a scientist by announcing false results that were collected from only a single trial.

</td></tr>
<tr><td colspan="2">Summarize (10 minutes)</td></tr>
<tr><td>Communicate</td><td>

Whole class discussion

- Was your team able to determine the shape of the hidden target?
- What was your process?
- Did you run into any difficulties? How did you resolve them?

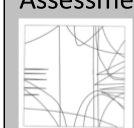
Questions

Why is it necessary to record the pathways of the marbles that miss as well as those that hit? What could you learn by observing the path of the marbles that hit?

Suppose you rolled the marbles from only one side of the box, could you tell:

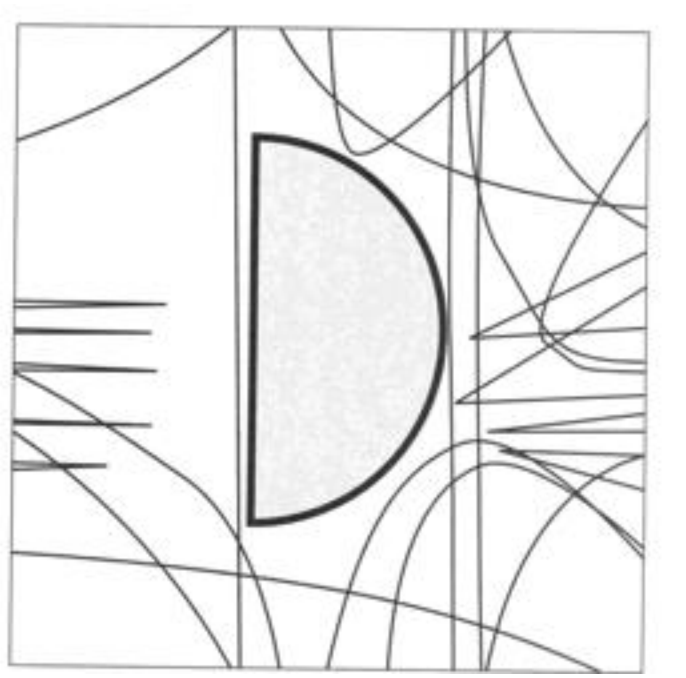
- The location of the target?
- The size of the target?
- The shape of the target?

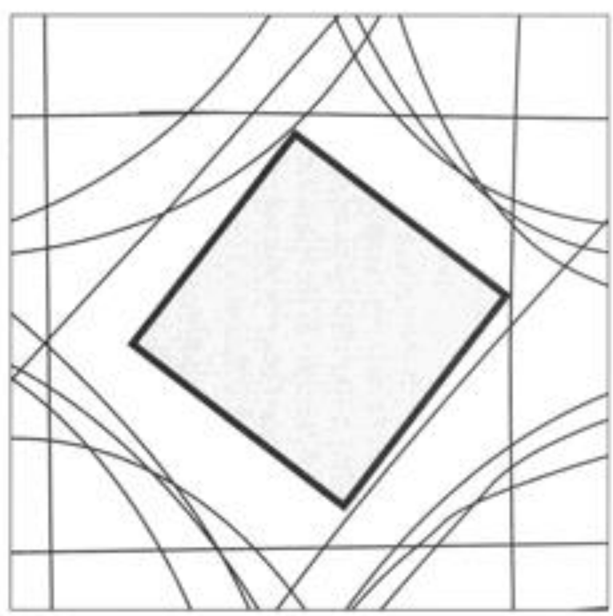
</td></tr>
</table>

	Then have the students think about what it must mean if most marbles roll through and only a few do not. • Is there something blocking the path? What is blocking the path? • Is it big or small? • Is the shape solid, or might it have gaps or spaces? Hold student discussion/ Have students record their responses before sharing aloud. • In this case, would the size of the marble matter? Why or why not?
Terminology and Concepts to Solidify	**Deflect-** change direction after hitting something **Rebound-** to bounce back after hitting something **Inference-** a conclusion reached based on evidence and reasoning **Direct evidence**- statements about an object (or phenomenon) that can be supported by observation **Indirect evidence-** statements about an object (or phenomenon) that are based on inference Example: Direct evidence- It rained. A person actually observed rain falling from the sky. Example: Indirect evidence- a person heard a distant pitter-patter and later walked out to find that the sidewalk was wet.
Connection to Big Ideas (Phenomena)	*Forces and Interactions* Unbalanced forces cause changes in an object's direction of motion When objects collide, energy can be transferred from one object to another, thereby changing their motion. *Evidence, models, and explanation* We can make inferences about matter we cannot see, such as the air in the paper towel challenge or the shapes under the Rutherford board. Just like other scientists, we need to make careful observations, and collect and record data to support these inferences.
Follow Up/Practice	Allow time for students to identify additional shapes. **Rutherford Scattering Interactive Simulation-PhET Lab** https://phet.colorado.edu/en/simulation/rutherford-scattering
Assessment 	**Sample Data Task** Give students a sheet of 'sample data' (see Print Masters) and have them determine the shape of the target indicated.

Exploring the Unseen

Sample Data Answers





Exploring the Unseen

Lesson 3	Model Students
Overview Standard(s) & Objectives	**Overview** During this lesson, students will be encouraged to think about how they learn new science concepts. As people acquire new information, it is organized into mental models. Mental models help us make sense of new information and to relate that information to other things that are already known. Mental models can be used to solve problems, make predictions, and generate explanations. **Building Toward** This lesson will focus on skills required to learn and do science. • Make observations • Develop and use a model (Science & Engineering Practice 2) • Ask questions (Science & Engineering Practice 1) and predict outcomes • Engage in argument from evidence (Science & Engineering Practice 7) • Use evidence to construct an explanation **Objectives** Students • Distinguish between inference and observation. • Recognize that learning involves building mental models. • Acknowledge that mental models help us think about the world around us. • Appreciate that drawing/sharing mental models helps build understanding. • Learn that mental models are used to solve problems, make predictions, generate explanations, and help us think about the world around us.
Background Information	Models can be physical, computational, or mental representations intended to stand in for some other thing, set of things, or phenomena. This lesson focuses on mental models. A mental model is an image of how something works in the real world. As learners acquire new information, it is always organized into mental models. Mental models help the learner organize all the new information acquired and to relate that information to other things that are already known. There is one property of mental models that should not be overlooked: they are often flawed in ways that significantly affect their utility. These flawed models may contain incorrect elements or relationships, or important elements and relationships may be missing. Such flawed models are often referred to as “misconceptions.” Misconceptions are known to be extremely resistant and can compromise learning about the phenomenon in question. Furthermore, it is not uncommon for individuals to possess multiple mental models, some from personal experience and others from classroom experience, some more or less correct and others completely inconsistent with current scientific views.

	In many cases, students have developed partially *correct* ideas that can be used as the foundation for further learning. Misconceptions can only be corrected when information that is considered more fruitful or useful to the learner than the previous information is added to their mental model to fill gaps, or correct misinformation. **Patterns in Scientists' Ways of Finding Out** 1. Creative and Critical Thinking: This involves coming up with new ideas, thinking outside the box, connecting imagination with logic, and then communicating these ideas to others. Many times these ideas go against the prevailing belief system. (e.g., Ray Davis- Solar Neutrino Problem) 2. Extensive documentation – Many scientists keep detailed notebooks, drawings and correspondence of comments, suggestions, and revisions of their ideas, lectures, and experiments. Documentation is a means of helping them to download thinking onto paper (reducing the memory load) and of helping them to see patterns that otherwise might go unnoticed. (Science notebooks) 3. Strong Powers of Observation - Many scientists' attention to detail and examination of research encompasses many years of investigation to reach their understandings. 4. Sharing of Information and Strong Collaboration with Others - Scientists often support ideas by looking across work in the field and synthesizing it. They work in collaboration, are open to ideas of others, and communicate extensively with colleagues. 5. Taking Advantage of Serendipity – Many discoveries happened while scientists were looking for something else, sometimes they were accidental, and sometimes after specific experiments provided surprising findings.
Materials	**Launch** • 1 stick string cheese • Lighter (preferred) or matches • 1 slivered almond • 1 coffee stirrer or an extra-long wooden pick Set up the 'candle' beforehand. Insert the stirrer/pick into the string cheese (long way) to reduce its flexibility. Put one almond sliver in an end to resemble a wick. Burn the almond sliver and blow it out so it looks like it has burned before, and so that it lights easier the second time. If desired, you may modify this setup with an X-acto knife for realism, or place object in a candle holder. **Notes:** The almond sliver "wick" will only burn for a few minutes. Once the oil in the sliver is exhausted, it goes out. Also, be aware of vents in classroom that may blow onto your "candle".

Exploring the Unseen

<table>
<tr><td></td><td>Explore
1 set of Inference cards per group of 4 students
Inference/Evidence Chart-1 per student</td></tr>
<tr><td>Prior Knowledge</td><td>This lesson is designed to focus on skills required to learn science. It contains no specific science content knowledge. This means that the students can learn about the nature of science without having to try to understand new science content at the same time.</td></tr>
<tr><td colspan="2">Launch (10 minutes)</td></tr>
<tr><td>Engagement and Communication of Student Expectations</td><td>Things are not always as they seem

Begin with a discussion on the definition of observation. Have students define observation. Common responses include:
Looking at something
Using any of your five senses to collect information
Making measurements
Introduce the demonstration by talking about the importance of good observations in scientific investigations. If possible, dim the lights and show students the object before lighting it in front of them—refrain from calling it a ‘candle’ throughout the demonstration.

Ask students to make observations about the object you are holding and write them in their science notebooks. Students are likely to provide descriptions of what they are observing (“There is a light being given off.”, or “I smell something burning.”) and also what they are inferring, incorrectly, based on prior experiences (“The wax is melting.)”.

After collecting student observations, gently blow out the flame, if it has not already extinguished itself. Ask for any final observations. Then, being mindful of the stirrer/pick casually take a bite of the ‘candle’, including the wick. The ‘wick’ may be hot so do not do this immediately. Make sure to chew and swallow your bite.

Students will be momentarily stunned. Without providing any explanation of what the ‘candle’ really was, steer the discussion toward the difference between observation and inference.

<blockquote>A direct observation is gathered via the senses and is done so without any preconceived assumptions about the object(s) you are observing. An inference, on the other hand, is an interpretation of or an explanation for an observation. Often times, inferences are drawn based upon observation and/or prior experiences. Inferences can range from being very reasonable conclusions to being weak guesses based upon faulty assumptions.</blockquote></td></tr>
</table>

Exploring the Unseen

Both direct observations and inferences play important roles in scientific investigations; however, we must be careful to avoid drawing erroneous conclusions based upon assumptions. Review with students some of the observations and inferences that they shared about the 'candle' and allow them to categorize their statements as "observation" or "inference."

Then, explain that today you are going to explore how we think and learn about science and how our prior experiences can sometimes steer us in the wrong direction.

Explore (30 minutes)

Procedure

Small Group Activity

Distribute Inference Cards and Inference/Evidence Charts.

- Tell students that their group will receive a packet of Inference Cards along with an Inference/Evidence Chart for each person. Their task is to write down 2-3 observations for each inference per photo. There are four sections, 1 for each photo. Students are expected to work with group members and share ideas verbally as well. (Additional choices on USB drive)
  This particular activity helps students solidify the difference between inference and evidence in both science and literacy.

Teacher Tip: As you monitor groups, watch out for those who may be confusing inferences and observations.

Whole class discussion

- Do you ever think about how you learn science?

1. Ask students to share the ways they go about learning. Have students (individually) make their own list in their science notebooks or journals.

	2. Once they have done this, have them share their lists in a group discussion. Write their ideas about how they learn science on the board or on large white paper. (Responses may include doing experiments, researching information on the web, talking to others, etc.) 3. Ask students to share any other ideas they have at this time. Follow up with these ideas and ask them to explain their thoughts. **Leading into mental models**… • How do our prior experiences sometimes influence our observations/expectations? (Think back to the 'candle') • During the Atomic Target practice lesson, how did you determine what shape was hidden under the cover? What did you observe? What did you infer? • How did your mental model change as you collected more data? • How might these discussions influence your thinking about the paper towel challenge? 4. Follow up with these ideas and ask them to explain their thoughts. How could we improve how we learn about science?
Questions	**Driving Questions** • How can models help us learn science? • Have you ever considered how your knowledge is organized? (*Mental models*) **Probing Questions** • Do you think that these scientists all came to their discoveries in the same way? • What do you think that all scientists have in common? • How do they go about learning science? • In what ways do you think like a scientist? • How do mental models help us learn? • How can drawing/sharing your mental models help build understanding? • Do mental models ever contain errors? • How can we correct these errors?

Exploring the Unseen

<table>
<tr><th colspan="2">Summarize (15 minutes)</th></tr>
<tr><td>Communicate</td><td>Whole class discussion- Mental Models
How do mental models help us learn? (Mental models help us make sense of new information and to relate that information to other things that are already known. Mental models can be used to solve problems, make predictions, and generate explanations.)
How can drawing/sharing your mental models help build understanding? (sharing your mental model, and considering others, may help challenge/improve your own metal model)
Do mental models ever contain errors? (yes)
How can we correct these errors? (share our models and get feedback from others, keep testing our ideas, don't be afraid to throw out what does not work to make room for what does)
Conclusion. In science, there is often more than one possible explanation for observations. Science is tentative and theories can change as new evidence is gathered. Therefore, our models must also change to allow us to think differently.</td></tr>
<tr><td>Terminology and Concepts to Solidify</td><td>Direct observation- personally seeing, feeling, hearing, or tasting something

Indirect observation- not sensing the object directly but observing the effects it has on its surroundings

Inference- a conclusion reached based on evidence and reasoning

Direct evidence- statements about an object (or phenomenon) that can be supported by observation

Indirect evidence- statements about an object (or phenomenon) that are based on inference

Mental Model- a "representation" of how something works. It is a concept, framework, or worldview that you carry around in your mind to help you interpret the world and understand the relationship between things. It is made up of interconnected, related pieces of information (knowledge) with the same "structure" as that which is being modeled.

Mental models serve many functions, including helping to make decisions or manipulate a system and helping to select, filter, and organize new knowledge as it is acquired.

The best mental models are the ideas with the most utility.</td></tr>
<tr><td>Connection to Big Ideas (Phenomena)</td><td>Evidence, models, and explanation

Models can be physical, computational, or mental representations intended to stand in for some other thing, set of things, or phenomena.</td></tr>
</table>

	Drawings can be created from mental models, to explain phenomenon. Students drew models of the paper towel challenge and the atomic target practice to help illustrate and communicate their mental model of what was happening.
Follow Up/Practice	Ask students draw/sketch a scientist doing science. (In a perfect world, they might draw themselves) Provide time for students to share their drawings with the rest of the class and to discuss observations, including similarities and differences among the drawings. • What do you notice about the scientists in the drawings? What do you wonder? Direct the students in a discussion of the impact that different stereotypes have on their perception of scientists in general. Some categories of traits students may come up with include: • gender (males vs. females) • ethnicity • with glasses • in traditional science lab • pencils/pens/pocket-protectors • showing science equipment • with "wild" or unruly hair Remind students that they are scientists and they do science! You may choose to close this session with students drawing a picture of themselves doing science in the classroom (or in the field.)
Assessment	Find 2-3 photos that can be displayed in your classroom. For each picture, ask the students to record at least 3 observations and 1 inference about the picture. Allow students time to share their observations and inferences, highlighting the idea that several different inferences can be made even when the observations are the same. (Each student has a different mental model)

Exploring the Unseen

Lesson 4	It's a Mystery
Overview Standard(s) & Objectives	**Overview** During this lesson, students will have the opportunity to investigate the unseen. Students will use indirect information gathered from experiments they conduct to derive conclusions about their mystery box. This lesson is designed to help students better understand the nature of science. In such work, scientists must rely on indirect information. Also in this lesson, students will experience the 'scientific community' approach by sharing and discussing their models with other student scientists. **Building Toward** This lesson will focus on skills required to learn and do science. • Use models (Science and Engineering Practice 2) to make predictions • Make observations • Engage in argument from evidence (Science and Engineering Practice 7) • Plan and carry out an investigation (Science and Engineering Practice 3) **Objectives** Students • Make multisensory observations. • Distinguish between observations and inferences. • Use indirect evidence to develop conceptual models. • Modify and revise models based on additional evidence. • Communicate models through discussion and drawing. • Recognize that science is uncertain because it is a human activity. • Understand that science does not prove or conclude – it is always a work in progress. • Demonstrate that science is a collaborative enterprise, and that scientific uncertainty can be reduced through collaboration.
Background Information	Scientists of all disciplines strive to understand how the world around us works. Often this requires that they study things that cannot be seen with the naked eye, or directly at all because what they study is so incredibly small (inside of cells/ atoms) or because it is too far away (other galaxies).

Exploring the Unseen

	Sometimes scientists can use tools to extend their senses, like microscopes or telescopes. Other times they must rely on indirect evidence – making inferences about 'detectable' information and trying to piece together what this information tells them about that which they cannot see. This particular activity helps to reinforce the difference between observation and inference. Science is not the orderly accumulation of knowledge. Rather, science requires imagination and creativity to provide inferential statements about observed phenomena. It allows students to see that observations can be made with non-visual senses (for example, auditory senses as they move their boxes around to determine its contents) and that observations can be aided by instruments (using a magnet against the side of the box, weighing it, using X-ray etc.) Since the students cannot open the mystery box, they can never be 100% certain about its contents. This helps students to understand that scientific knowledge is tentative.
Materials	*For each student:* • Science notebook **Gift Box** • 1 box, wrapped in decorative paper **Mystery Boxes** • Rigid, opaque boxes Each 'Mystery Box' is a rigid, permanently sealed, opaque, box with one or two glued-in partitions, ramps, etc., and a rolling sphere (e.g. a marble or steel ball). A class set of boxes should have several groups of boxes with the same interior contents and arrangement, with common letter labels (e.g., Boxes A, B, C, D).
Prior Knowledge	The activity is designed to explicitly teach ideas about the nature of science. It contains no specific science content knowledge. This means that the students can learn about the nature of science without having to try to understand new science content at the same time.
Launch (5 minutes)	
Engagement and Communication of Student Expectations	Tell the class that you received a surprise gift from an unknown sender. Your only clue was a tag that said 'Do not open until…' (Choose a date that is a short distance into the future.) Place the Gift Box in a place where all can see it.

Tell the class that you are very curious about its contents. Ask for advice about how you might determine what it is without opening the package. Write all suggestions on board. As a class discuss the list. Are all suggestions appropriate for the task? Why or why not?

Connect to previous lessons. What is the difference between an observation and an inference? Turn and talk.

Tell the students:

Today will use observations to make inferences about things you cannot see.

Now tell the class that they will have an opportunity to investigate the ‘unseen’.

They will each receive a lettered mystery box (not all of them are the same). The task is to determine what the interior of the box looks like, without opening the box.

Note: The goal is to decide what shape is glued inside the box, not to say that there is a marble in the box. You may need to let students know the marble is being used as a tool just like it was in Atomic Target Practice in Lesson 2.

Explore (35 minutes)

Procedure

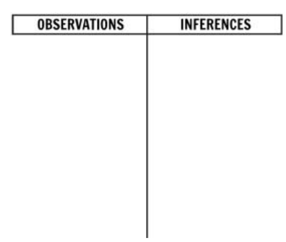
Observing

1. Hand each student a box. Connect to the previous lesson and ask: What is the difference between an observation and inference? Turn and talk.
   Ask students to *leave the box on their table and use their sense of sight* to begin making their observations, *not* inferences. The box must remain closed.

   “It is red” is a valid visual observation.

   “It is pretty”, “It is a golf ball”, or “It would make a nice box for a gift of fudge” are inferences.

2. Guide students in creating a T-chart on the board for them to copy into their Science Notebook and modeling how to make an observation, if necessary. Their description should include using our senses to describe the size, shape, color, texture, etc. of an object. Students write initial observations in science notebooks.



3. Then ask them to make as many observations as they can with all their senses *without* opening the box. For example, they can feel the box, smell it and shake it to listen to it. They should be describing size, shape, texture, what they hear, etc. Students write additional observations in science notebooks. (No violent shaking or hard pressing- boxes can break.)

Exploring the Unseen

Predict & Model

4. Tell students that their next task is to think about what the inside of the box looks like. Think back to the mental models from the previous lesson. Concentrate on the LOCATIONS and SHAPES of the things inside the boxes. Do not worry about what they are made of.
5. Have students imagine that they are standing above the box looking down at it. If they could see through the top, what would the inside look like? What is your mental model about what is inside the box?
6. Have students draw their mental model (their first prediction) in their science notebooks.

Share

7. Have them share observations with their partner. Ask them to use these observations to make a prediction about what the object(s) inside the box is. After conferring with their partner- have them draw their revised prediction in their science notebook.

Note: Students with the same lettered boxes will likely:

- Make different observations
- Interpret their observations differently
- Reach different conclusions

Students may want to change their predictions if they are presented with new evidence – for example; if different members of their research team might interpret an item's location/size differently-they may wish to revisit their lettered box.

You may need to tell students that scientists work collaboratively in teams and use tools and scientific techniques to make better observations.

Whole class discussion

8. As a class, discuss how confident they are about their predictions:

   As a scientist, would you be prepared to publish your findings in an academic journal, present them at a prestigious conference or stake your reputation and career on your findings?

9. Discuss what they could do to be more confident. For each option they offer, draw the analogy to how scientists work.

Here are some possible student responses and comparisons with the work of scientists:

Possible student responses	Analogies to the work of scientists
We could hold a magnet against the side of the box or weigh it or x-ray it.	Scientists use technology to enhance their observations, but sometimes, the most useful technology may be unreasonable.
We could get another box, put what we think it is inside it and then compare them.	Scientists make models to test.

We could team up with another group with the same box and compare our findings.	Scientists collaborate.
We could swap boxes and get another group to check our results.	Scientists replicate the work of others to support or challenge their claims.
We could open the box.	This is a clear point of difference because scientists often cannot make direct observation. For example, they can't: Cut the Earth or Sun in half See inside an atom Go back in time to see the dinosaurs or the rock formations. In many cases like these, they must rely on indirect observation and inference.

10. Let students devise a plan (utilizing some of the ideas above) to gather additional evidence, until they are more confident about their prediction.

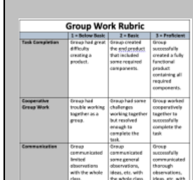
With your partner

- Talk about your experiments, your ideas about what the interior of your box looks like, and your evidence for your ideas.
- Conduct further explorations to refine your ideas and envision how the interior of your box looks.
- Draw a preliminary sketch of the inside of your box.

If time allows -With another pair with identical mystery box

- Discuss your models for the interior of your box.
- Continue to refine what you believe the inside to look like based on your discussions and new evidence.
- Prepare to present your model to the whole group.

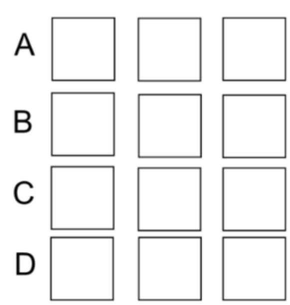
The *Group Work Rubric* can be used to assess collaborative processes.



Group Work Rubric

	1 = Below Basic	2 = Basic	3 = Proficient
Task Completion	Group had great difficulty creating a product.	Group created the end product that included some required components.	Group successfully created a fully functional product containing all required components.
Cooperative Group Work	Group had trouble working together as a group.	Group had some challenges working together but resolved enough to complete the task.	Group worked cooperatively together to successfully complete the task.
Communication	Group communicated limited observations with the whole class.	Group communicated some general observations, ideas, etc. with the whole class.	Group successfully communicated thorough observations, ideas, etc. with the class.

11. Each team should put the drawing of the inside of the box on the board. (Prepare the board by writing the letter of each box in a separate area on the board and drawing enough boxes to equal the number of students who have that lettered box.)



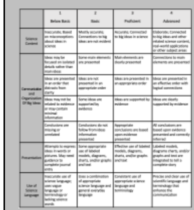
Allowing students to see drawings of several other models (proposed by their classmates) can help the students to re-evaluate their model and make refinements if necessary.

	Note: Students are often frustrated by not being able to see the inside the box. Having students construct a model of what they think the inside of the box looks like further models the process of science and is one way to address this frustration. Another possible approach is working with different models that had been proposed by others, either drawings/diagrams or physical models. • Don't tell or show them if they are right or not! • You may use this as a springboard to discuss how scientists often have to form hypothesis from indirect observations. The fact that there is no right answer and that several models can work should be emphasized. **Extension** Have students build their models out of spare boxes, to see if they behave as the original. This would provide the opportunity to talk about refining the model and how, in science, experiments must be repeated many times to make improvements.
Questions	As students work, circulate first to address any procedural questions and then to listen to what students are talking about and to ask probing questions (see below) to further their thinking. **Driving Question** • How do scientists/we learn about things that can't be seen or touched? **Probing Questions** • Are there any obstructions in the box? What's your evidence? • Do you think there is a single object, or multiple objects in the box? • How confident do you feel about your prediction? • What do we as scientists do when we need more information?
Summarize (15 minutes)	
Communicate	**Whole class discussion** When each pair has drawn its agreed upon interior configuration, have a class discussion about the procedures that the group used. Have someone from each group describe the process that their group went through to arrive at its final drawing. (Group Role- Reporter) Guide them to tell what they *did*, not what they decided. This will not be easy for them. (They might share that they traded boxes, compared impressions, told, and showed others how to investigate a box and what to look/listen for. You may want to describe several interactions you observed while they were working.)

Exploring the Unseen

	Ask students how confident they feel about their drawings now and what makes them feel that way. Discuss how what they have done is similar to how other scientists work. There are many things scientists know about without ever having seen them. We know about black holes, the inside of the Earth, etc. based upon data scientists have collected without ever having seen these things. Talk about science being uncertain and that ideas in science can change when we get more information. Collect the boxes when the discussion about their investigative techniques and their relationship to how scientists work is finished. Students will usually want to know if their drawing is 'right'. Talk about the process we used: gathering data through our senses and making a logical inference based upon that data. Help students to realize that, in science, we will never know the 'right' answer to any scientific question, but we often come close enough for practical purposes and future exploration.
Terminology and Concepts to Solidify	**Black box-** a device, system, or object whose contents are a mystery because they cannot be observed directly **Model-** a representation of the world often based on evidence from experiments. Models allow scientists to make predictions, and design further experiments to test the validity of the model. Often these new experiments and the evidence that comes from them will force refinement of the model, much as when groups came together in the class conference, you were forced to incorporate the data (and interpretations) of others, and thereby refined your model. Only when something is reproducible over and over and over does it become accepted as a working model. This process of refinement through evidence, and discussion/argument is critical for the advancement of scientific knowledge.
Connection to Big Ideas (Phenomena)	*Evidence, models, and explanation* We can use indirect evidence to make inferences about matter we cannot directly observe. *Uncertainty, Collaboration & Scientific Argumentation* Hypotheses/models change with new information and through collaboration with others.
Follow Up/Practice	Have the students reflect on what they learned from this activity. Students could also build a mystery box of their own design.

Exploring the Unseen

Assessment 	Students' understanding can be noted in how they make progress in their discussions and models. In this activity there is no right answer, as the box is never opened. (See *Science Notebook Rubric*) Students’ collaborative processes can be assessed using the *Group Work Rubric* provided.

Lesson 5	Condensation Conundrum: No Sweat!
Overview Standard(s) & Objectives	*Explorations in lessons 5 and 6 will not work if the humidity is too low. It is advisable to test classroom conditions by checking to see if a glass of ice water will produce condensation. **You may choose to run a room humidifier the night before.** **Overview** Students investigate the condensation of water vapor on the outside of an empty can. In the next lesson, students will change one variable as they design their own investigation. **Building Toward** 5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen. Crosscutting Concept • Scale, Proportion, and Quantity -Natural objects exist from the very small to the immensely large. Science and Engineering Practice • Developing and Using Models- Use models to describe phenomena. **Objectives** Students • Follow procedures to create condensation. • Draw on direct (observable) evidence to explain condensation. • Reason about the existence of water vapor in the air.
Background Information	Condensation is the process by which molecules of a gas slow down, come together, and form a liquid. Water vapor is entirely invisible. It should not be confused with steam or a cloud or fog. Steam and clouds and fog are all made up of tiny liquid water droplets that are suspended in the air. Liquid water droplets are visible, but water vapor is not. When gas molecules in the air transfer their energy to something cooler (the can), they slow down, and their attractions cause them to bond to become a liquid. * Try the demonstration before using it with your students because it will not work if the humidity is too low. In that case, show the following video and encourage students to draw on personal experiences with drinks “sweating” and continue to the Communicate part of the lesson. Video: Condensation (55 seconds) https://www.youtube.com/watch?v=bymT5AcV-C4

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<table>
<tr><td>Materials</td><td>For each student:
Science notebook
Planning an Investigation handout
Design Your Own Experiment handout
For each pair (or small group) of students:
One clean, empty can without label
Ice water
Paper towels
Magnifying glasses (optional)
Teacher Tip: Put ice in pitchers before the experiment to make sure water is as cold as possible.</td></tr>
<tr><td>Prior Knowledge</td><td>Different kinds of matter exist and many of them can be either solid or liquid, depending on temperature.

Making inferences (reasoning about what is “unseen”)

Matter is made of particles too small to be seen.</td></tr>
<tr><td colspan="2">Launch (5 minutes)</td></tr>
<tr><td>Engagement and Communication of Student Expectations</td><td>Tell students:
Today you are going to do the work of scientists. On the first day, you will perform an experiment to observe a phenomenon, and then reason about what is happening and why. On the second day, you will design your own variation of the experiment to answer a question you still have.

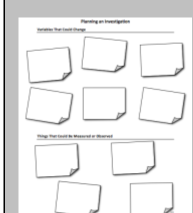
There will be some things happening that you cannot actually see so you will need to use indirect evidence to make inferences about what causes certain results. Observe carefully and take notes in your science notebooks about what is happening and why you think it is happening.</td></tr>
<tr><td colspan="2">Explore (20 minutes)</td></tr>
<tr><td>Procedure</td><td>Using what you know
Give each pair, or group, of students an empty can. Tell them they will be filling the can with ice water. Have students make predictions about what they think will happen and to record their predictions in their science notebooks.
Ask students to observe the can, fill it ½- ¾ with ice water and then continue to observe. If they are using magnifying glasses, encourage them to use these tools to look closely at the can.</td></tr>
</table>

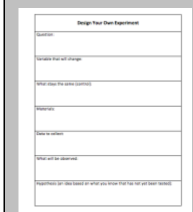
	3. Post the following and have students respond in their science notebooks: • Observe the sides of the can closely and describe what you see. (Direct evidence) • What explanations can you give for these observations? (Mental models/indirect evidence) As students work, circulate first to address any procedural questions and then to listen to what students are talking about and to ask probing questions (see below) to further their thinking.
Questions	**Driving Questions** • Where did the moisture on the outside of the can come from? • What evidence do you have to support your thinking? **Probing Questions** • What did you observe happening to the outside of the can? • What happens if you lightly touch the outside of the can with your fingertip? • What did the 'stuff' look like as it was forming? • What is it made of? How do you know? • Do you know what this process is called? • Does it cover the entire outside of the can? • Is there a distinct line above which the stuff does not form? Does this line match the water line inside the can? • Does the line change height over time? (It might creep upwards as the upper portion of the can gets colder. It might also start to move back downwards if the water in the can warms up above freezing.) **Teacher Tip** Some students may have misconceptions about where the moisture on the outside of the can came from. Refrain from giving them additional information about condensation and allow them to test their mental models in the next lesson. Ice cubes may not be uniform and can account for some interesting results gathered by students. **"What If" Questions** The "what if" questions are designed to get students thinking about designing their own variation to the experiment in Lesson 6. Listen for other questions students might be wondering about and be able to test. • What if the water was hot? • What if the water had food coloring? • What if you used a liquid other than water?

<table>
<tr><td></td><td>

What if you used a container made of a different material (e.g., plastic, wood)?
What if you used a sealed can?
What if ice was placed on or around the can?
What if the can was inside a plastic bag?
What if you pulled an empty can from the freezer without any ice water at all?
What would happen if the temperature is lower? (Take experiment outside?)

</td></tr>
<tr><td colspan="2">Summarize (30 minutes)</td></tr>
<tr><td>Communicate

</td><td>
Whole class discussion
Ask students to share some of their actual observations (direct evidence). Then have them make inferences and reason to explain what was happening (mental models/indirect evidence). Emphasize that scientists often need to use what they can see to try to understand and explain phenomenon they cannot see. Ask if anyone knows what the phenomenon of water drops forming on the outside of the can is called (condensation).
Have students share any personal experiences they have had with condensation (water bottles, mirrors, windows, etc.) How did these experiences influence your mental models?
Make connections to evaporation (puddles, sweat, glass of water left out etc.) While condensation is when matter changes from gas to liquid, evaporation is when matter changes from a liquid to a gas. Ask students what they think happens to the water when it evaporates.
Explain that students will be designing their own variation of the condensation experiment to answer questions they may still have. Ask them what they still wonder about, and record their ideas.
This can easily be done by having groups write down what if questions to share. Once groups have their questions, one member per group will write their “What If” questions on a board or chart. If they do not bring them up, you may add some of the “What If” questions from above.
Plan your own investigation
For students who have limited exposure to planning experiments, investing some time in this discussion will be beneficial.
Tell students that, in the next lesson, they are going to do their own experiment but, this time, they will change one of the variables to find out if it will make a difference in the results.
Explain that a variable is a factor that can be changed. Ask students to name some of the variables in this experiment (e.g., type of container, the temperature of the water, type of liquid).
</td></tr>
</table>

	Have students record ideas on the *Planning an Investigation* handout. Discuss why scientists might only change one variable at a time in an experiment. Explain that this process of isolating the effect one variable at a time is called a controlled experiment. Brainstorm things that could be measured or observed (*e.g., water coming from can, color of water, temperature*). **Design your own experiment** Organize students into groups of four and hand out the *Design Your Own Experiment* sheet. It can be helpful to show students what materials are available for them in the kit and any additional items found in the classroom. Students complete the first four sections of the plan. Have each group choose a “what if” question they would like to investigate. Remind them that their question must be testable and must not require specialized equipment. This will provide you with advanced notice of any materials that might need to be gathered. Emphasize that scientists conduct controlled experiments, changing only one variable at a time so they can see the effects. Students design the experiments as a group; however, each student must complete the plan. Plans need to be kept for the next lesson.
Terminology and Concepts to Solidify	**Observation**- information gained directly through your senses **Direct evidence**- statements about an object (or phenomenon) that can be supported by observation **Indirect evidence-** statements about an object (or phenomenon) that are based on inference **Condensation-** the process by which molecules of a gas slow down, come together, and form a liquid The cold can is a simple type of “detector.” It provides a way to detect the presence of an invisible substance, water vapor, in the air. This is related to what scientists at SURF are doing—figuring out ways to try to detect invisible substances. **Controlled experiment-** an experiment that isolates the effect of one variable in a system by holding constant all variables but the one under observation **Variable**- any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of **variables**: independent, dependent, and control. The **independent variable** is the one that is changed by the scientist. The **dependent variable** is what you measure in the experiment and what is affected during the experiment. The **control variable** is held constant in order to assess or clarify the relationship between two other variables.

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Connection to Big Ideas (Phenomena)	*Structure and properties of matter* Matter (water vapor) is made of particles too small to be seen. *Evidence, models, and explanation* We can use our senses to gather evidence for condensation. We can use direct evidence to reason and develop explanations for condensation.
Follow Up/Practice	Look for places in and around home where condensation appears. Write a journal entry about other forms of moisture in the air that they can see: rain, clouds, fog, their breath in the air, snow, etc. Investigate further the components of the water cycle.
Assessment 	Listen to students and read science notebook entries to determine: • Are students describing the observations of their can as water condenses on it? • Are students constructing logical explanations about where the moisture on the outside of the can came from? *(See Science Notebook Rubric)*

Lesson 6	What If…Exploring Testable Questions
Overview Standard(s) & Objectives	**Overview** Students continue their investigation by observing condensation under a variety of conditions. They design their condensation experiment, changing one of the variables. **Building Toward** 5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen. Crosscutting Concept • Scale, Proportion, and Quantity -Natural objects exist from the very small to the immensely large. Science and Engineering Practice • Developing and Using Models- Use models to describe phenomena. **Objectives** Students • Ask a question about condensation that they can test by doing a variation of the can experiment. • Design an experiment to test their question. • Make and record observations of condensation under various conditions. • Use evidence to construct an explanation about the results.
Background Information	Gather materials that groups will need to investigate the question they formulated in the previous lesson. A controlled experiment is one that isolates the effect of one variable of a system by holding constant all variables, except the one under observation. When someone breathes on the window or a mirror, his or her breath is quite warm and has lots of water vapor in it (very humid). Even when the window or mirror isn't particularly cold, it's still usually enough colder than body temperature to cause condensation (but the condensation typically evaporates quite readily afterwards). On a cold day, the vapor in your breath condenses when your breath mixes with cold air (you can "see your breath"), but usually those tiny liquid droplets evaporate quite readily, and your breath "disappears" again.

Exploring the Unseen

Materials	*For each student:* • Science notebook • Partially completed *Design Your Own Experiment* sheet For each group of four students: • One clean, empty can • Paper towels • Magnifying glasses (optional) Additional materials for each group may include: • A second can • Hot water • Ice • Salt • Food coloring • Tall glass • Full can • Zip top bag • Thermometer • Insulated plastic tumbler
Prior Knowledge	Different kinds of matter exist and many of them can be either *solid* or *liquid*, depending on temperature. Making inferences (reasoning about what is "unseen") Matter is made of particles too small to be seen.
Launch (10 minutes)	
Engagement and Communication of Student Expectations	Ask for a volunteer to go and breathe on the window to make "fog" appear. Ask students where the moisture on the window came from and how it got there. Make the connection to the condensation experiment from the previous day. Ask students to share any other examples of condensation. **Teacher Tip:** If the window is too warm when students breathe on it, then 'fog' won't form. Try a cooler glass surface or mirror. Tell students that today they are going to investigate the process of condensation more closely by designing their own experiment.

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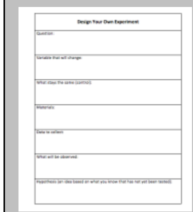
<table>
<tr><th colspan="2">Explore (30 minutes)</th></tr>
<tr><td>Procedure

</td><td>

Experiment

1. Complete the plan. Have students get into their groups from the previous day and review their *Design Your Own Experiment* plan. Have them work together to complete the "Data to collect" and "What will be observed" sections.
2. Make a hypothesis. Give students a few minutes to discuss their current mental model of the condensation process and what they think will happen in the experiment with the change of a single variable. Introduce them to the term "hypothesis" (an idea based on what you know). Remind students that, prior to the experiment, they made predictions about what they thought would happen. Now that they know more, they can make a more informed prediction called a hypothesis.
3. Investigate. Have students carry out their experiment and record their observations. As students work, circulate first to address any procedural questions and then to listen to what students are talking about and to ask probing questions (see below) to further their thinking.

</td></tr>
<tr><td>Questions</td><td>

**Questions will depend on each group's investigation.*

Driving Questions

- How are the results of this experiment the same or different from the first experiment?
- How did changing one of the variables affect your understanding of the condensation process?
- If the particles of matter are too small to be seen, how do we know they are there?

Probing Questions

- What did you observe happening to the outside of the can?
- What color is the water on the outside of the can? How do you know?
- Where do you think the water comes from?
- How do you think it got there?
- What evidence do you have to support your thinking?
- Why do you think we can't see where the water comes from?
- What explanation can you give for your observations?

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Summarize (15 minutes)	
Communicate	**Whole class discussion** Have each group briefly share what happened in their investigation and why they think it happened. Ask students: • What was your observable (direct) evidence? • What inferences did you make about the unseen (indirect evidence)? • How did your mental model change as a result of your observations? **Teacher Tip:** Students may need more scaffolding for sharing observations and evidence. A T-Chart for group responses may help.
Terminology and Concepts to Solidify	**Controlled experiment-** an experiment that isolates the effect of one variable in a system by holding constant all variables but the one under observation **Variable**- any factor, trait, or condition that can exist in differing amounts or types An experiment usually has three kinds of **variables**: independent, dependent, and control. The independent **variable** is the one that is changed by the scientist. The **dependent variable** is what you measure in the experiment and what is affected during the experiment. The **control** is held constant in order to assess or clarify the relationship between two other variables. **Mental Model**- a "representation" in memory of information that has been acquired. It is made up of interconnected, related pieces of information (knowledge) with the same "structure" as that which is being modeled. Mental models serve many functions, including helping to make decisions or manipulate a system and helping to select, filter, and organize new knowledge as it is acquired **Hypothesis**- an idea based on what you know, that has not yet been tested
Connection to Big Ideas (Phenomena)	*Evidence, models, and explanation* We can use our senses to gather evidence for condensation. We can use direct evidence to reason and develop explanations for condensation. Mental models change with the gathering of new evidence. After scientists at the Sanford Underground Research Facility have come up with a basic way to try to detect something they cannot see, then they work to refine it or adjust it to better understand the properties of the material they're interested in—just the way that students in this lesson refined their water vapor detector and learned a little more about the behavior of water vapor.

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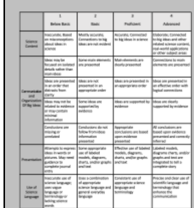
Follow Up/Practice	Students could explain evaporation using what they know about condensation. Create a model to explain 'fogging' up a cold window, warm breath in cold air, or evaporation and condensation in the water cycle. Or, Create a poster of the results of their investigation to share with the class.
Assessment 	Utilize science notebook rubric. Listen to students, and read science notebook entries and lab sheets to determine: • Do students make logical predictions? • Do students clearly isolate and test a single variable? • Do students make reasonable inferences to explain what happened?

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Lesson 7	Pulling it All Together
Overview Standard(s) & Objectives	**Overview** During this lesson, students will explore the concept of refraction. Students will learn how the bending of light is used as one piece of evidence (gravitational lensing) to support the existence of a real-life mystery 'dark matter.' **Building Toward** 4-PS4-2 Develop a model to describe how light reflecting from objects and entering the eye allows objects to be seen. Crosscutting Concept • Cause and Effect- Cause and effect relationships are routinely identified. Science and Engineering Practice • Developing and Using Models- Develop a model to describe phenomena. 5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen. Crosscutting Concept • Scale, Proportion, and Quantity -Natural objects exist from the very small to the immensely large. Science and Engineering Practice • Developing and Using Models- Use models to describe phenomena. **Objectives** Students • Learn that light typically travels in a straight line until it strikes another object. • Observe simple objects, patterns, and events and report their observations. • Learn that light can change direction when it crosses the interface between two substances -- like the interface between air and water (Refraction). • Use data to construct a reasonable conclusion. • Explore some ways light behaves and later make connections to the concept of dark matter.

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Background Information	
	Reflection & How We See Every object that can be seen is seen only because light reflecting from that object travels to our eyes. If there is no light, people can see nothing. Light is a vital part of how our eyes work. Reflection happens in two different ways. One way that light reflects is when it hits a smooth, polished surface, such as a mirror. The light beam will bounce off the surface of a mirror and change direction. This is called *specular reflection*. Most objects are rough rather than smooth. When light hits these objects, light is scattered. This is called *diffuse reflection*. This is how we see most things around us. **Refraction** Light tends to travel in straight lines, like you would see with a flashlight. However, when light travels from one material, (also known as a medium) such as air, through another material, such as water, something interesting happens. Water slows down the light, just like it slows you down when you walk in it. This makes the light waves bend where the air and water meet (the boundary) then change directions once again traveling in a straight line. This is called ***refraction*.** If when viewing an object, light from that object travels through different media on the way to your eye, a visual distortion is likely to occur. Transparent materials (such as glass) cause refraction. Refraction is really very useful. In fact, people who wear glasses are helped by refraction. The lenses in glasses are curved shape pieces of glass or plastic that can bend light and make them appear closer or farther, depending on what your eye needs. So basically, eyeglasses slow down light so that it can change direction and help a person's vision. **Refraction and the Straw and the Cup Activity** With the cup and the straw activity, the bending will happen at the junction of the air and the water. **What is Happening with the Penny in the Cup of Water?** The penny cannot be seen until more water is added to the cup. When the water level rises, the light from the penny travels from water (a more dense material that causes it to slow down), to air, (a less dense material that causes it to speed up). The light changes speed and it bends as it leaves the water and enters the air. The person observes the penny in a place that appears to be higher in the cup than it really is. See video below for demonstration: ***Refraction of Light Explained Through Cup, Water and Coin** - Science Experiments for Kids April 15, 2013 https://www.youtube.com/watch?v=s3EK1lGkf2s

Exploring the Unseen

What is Dark Matter?

Over the past few decades, scientists have discovered that 'regular' matter – all the stuff we can see and feel like stars, planets, rocks, clouds, and gases – only accounts for a small fraction of the total mass in our Universe. Other mass in our Universe is referred to as "Dark Matter." Dark matter has been given this name because it doesn't reflect or emit light. We can't see it or detect it with any of our instruments. It doesn't seem to interact with regular matter in any way, except through gravitational attraction. It doesn't collide with regular matter or absorb energy from it. We only know it's there because we can see how dark matter affects other things gravitationally. It's a mystery that can only be studied by indirect evidence.

Gravitational Lensing

One type of evidence for the existence of dark matter comes from looking at distant galaxies. Telescopes that look deep into space show distorted images of the distant galaxies. Einstein first predicted this in his theory of relativity. The theory predicts that large masses in outer space, such as clusters of galaxies, bend light that travels near them. However, sometimes light traveling through space is seen to bend unexpectedly, without traveling near a known massive object. In these cases, the bending is attributed to the presence of 'dark matter.'

With practice, astronomers have gotten better at detecting dark matter by observing the effect of its gravity on the path that light takes as it crosses the Universe. As light travels through a region of dark matter, gravity distorts its path. Instead of taking a straight line, the light is bent a certain amount depending on how much dark matter it passes through.

Using this evidence, astronomers can then map out regions of dark matter in the sky just by looking at the distortions in the light, and then working backwards to figure out how much intervening dark matter would need to be there to cause it.

For more information, here is a TED Talk with an overview of Dark Matter that can be viewed online.

Thaller, Michelle, TED Talk: Dark Matter - What We're Really Made Of: Michelle at TEDx Binghamton University (19 mins 45 seconds)

Published on Mar 7, 2013

Michelle is the assistant director for science communication and higher education, NASA Sciences and Exploration Directorate, and specialist in the lifecycles of stars

https://www.youtube.com/watch?v=lYH_nFwMXRM

(If you choose to play this directly from the link, you will wish to move past the theme before sharing with students) The theme has been removed from the USB version.

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<table>
<tr><td>Materials</td><td>For each student:
Science notebook
Launch
Compact mirror
Flashlight
For each group
Transparent cup (tall, clear)
Straw
Water
Explore
For each group
Plastic container (deli style)
Paper to wrap container
Penny
Transparent tape
Permanent marker
Meter tape
Ruler
Water
Large colored solo cup to pour water from
After activity you will need:
Hubble Telescope Pictures (on USB drive)</td></tr>
<tr><td>Prior Knowledge</td><td>Students should know that light travels in a straight line, like when you use a flashlight.

Students should know that objects can be seen because light reflecting from that object travels to our eyes. (1-PS4-2: Construct an evidence-based account for how objects can be seen only when illuminated. 4-PS4-2: Develop a model to describe how light reflecting from objects and entering the eye allows objects to be seen.)

Students should have some experience with scientific reasoning.

Students should know that the universe consists of many objects, including stars, planets, galaxies, and clusters of galaxies.

Matter is anything that occupies space and has mass.</td></tr>
</table>

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<table>
<tr><th colspan="2">Launch (10 minutes)</th></tr>
<tr><td>Engagement and Communication of Student Expectations</td><td>
In small groups, explain to the students that they are going to place a straw in a tall transparent cup with water in it. Ask them to predict in their science notebooks what they will see. Students may say: nothing will happen, the straw will look bigger, or the straw will look smaller. Their prediction should include a drawing.
After predicting, they will fill a clear cup ¾ full of water, and then place a straw in the cup. Then they will write/draw observations in their science notebook. (The straw appears to be broken where the air meets the water.)
Remind students to use specific words (i.e. not “it”, but “the straw” or “the water”).
The teacher will facilitate a classroom discussion by posing the questions:

What do you notice about the straw once it's in the water?
Does this match your prediction?
Why do you think this happens?
Does the straw actually change?
Does the straw actually get bigger/smaller?
Does your observation change if you tilt the straw differently?
What do you predict would happen to your perception of the straw if it were placed halfway in a glass of water?
Does this remind you of a tool you have used? (a magnifying glass)

Depending on time available, you may wish to have students observe an upright straw as it is moved from the center of the cup toward the viewer's left or right side - and also forward and back.
As you question students, it is helpful to repeat their observations to help them formulate and write them in their notebooks.
Then ask students: How does light travel? (They should know it travels in a straight line unless it hits something to cause it to change direction.) Demonstrate this with the flashlight. Then, using the mirror, demonstrate how the light can be redirected. Tell them that today we are observing how light travels.
</td></tr>
<tr><th colspan="2">Explore (30 minutes)</th></tr>
<tr><td>Procedure</td><td>
Refraction

Work with a partner. Place the penny (centered) in the bottom of the plastic deli container with paper wrapped around the sides.

It may be necessary to tape the penny into place, so that it does not move.
Label one side of the container with your name, and the other side with your partner’s name.
Set the container near the table's edge. (Name facing outward)

</td></tr>
</table>

4. Stand directly in front of the container. Stand close enough so you can see the penny in the bottom of the container.

Part 1

5. Move slowly backward (in a straight line) until you can no longer see the penny. Your partner should record your distance from the container in centimeters. (Stay put for part 2) Record this information in your science notebook.

   There may be some discussion required about how to measure…from toes, heels? Does it matter?

Part 2

6. Your partner will then slowly add water to the container until you tell him/her that you can see the whole penny. (From your stopping spot)
7. Mark the water level on the side of the container.
8. Use a ruler to measure how much water is now in the container. Record the depth in centimeters/millimeters in your science notebook
9. Switch roles. Repeat part 1 and part 2.

As students work, circulate first to address any procedural questions and then to listen to what students are talking about and to ask probing questions (see below) to further their thinking.

Questions/Discussion

- Did you and your partner have the same data?
  - If so, why?
  - If not, why not?
- How did your distance from the container and the depth of water required for you to see the penny compare to your partner's?

Teacher tip: It may be help students understand that the difference in data is related to the height of the observer. Ask students to line up according to: the distance required to lose sight of the penny, the depth of water required to see the penny again.

- Did the penny ever move during this exploration?
- What made it possible for the penny to come into view again?
- What observations about the penny did you make as the water was being added to the container?

<table>
<tr><td></td><td>
Individual sense-making
<ol start="10">
In your science notebook, explain how adding water to the container made it possible to see the penny again. Encourage students to diagram, using straight lines only, to show how light travels between their eye and the penny.
Part 3
<ol start="11">
Position yourself again so you can see the whole penny with water in the container. Have your partner remove the paper so that the penny is now visible through the side of the container.
What do you notice?
Can you see two (or more) pennies now? Is there really more than one penny?
Briefly discuss this. (Note: Students may see multiple pennies depending on the light and angle at which they are looking at the container.)
</td></tr>
<tr><td>Questions</td><td>
Driving Question
How does light travel through water?
Probing Questions
Did you and your partner have the same data?
If so, why?
If not, why not?
How did your distance from the container and the depth of water required for you to see the penny compare to your partner's?
Did the penny ever move during this exploration?
What made it possible for the penny to come into view again?
What observations about the penny did you make as the water was being added to the container?
</td></tr>
<tr><td colspan="2">Summarize (15 minutes)</td></tr>
<tr><td>Communicate</td><td>
How science works
Someone notices something unusual, and then people propose ideas to explain it. The idea that best matches reality is considered correct. For most of us, science arrives in our lives packaged neatly as fact. But how did it get that way? In this unit, we have learned much about how scientists learn and reason about things we cannot see or touch.
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Real-World Connection: Sanford Underground Research Facility

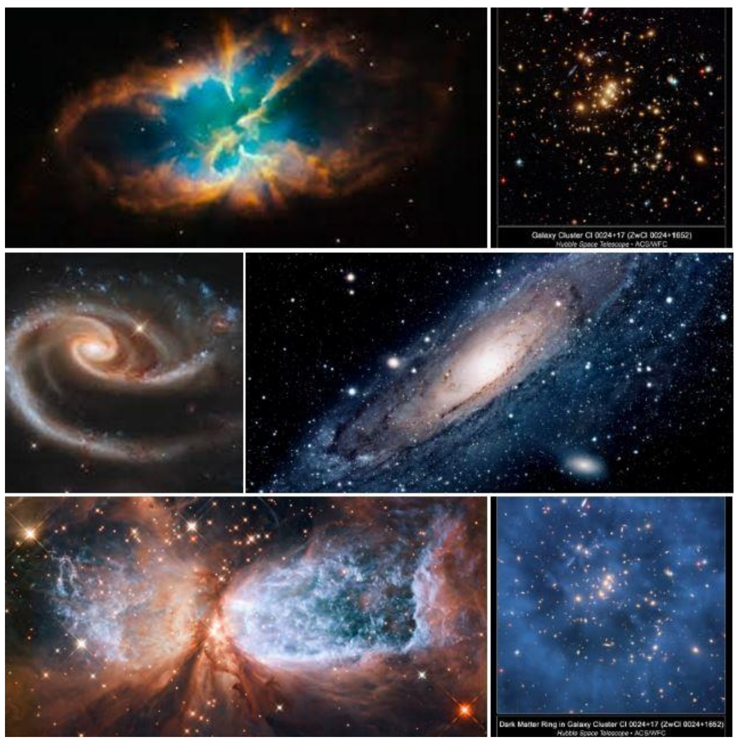
What happens when there is evidence that something is there, but no one has any idea what it is? (See background)

- Collect clues
- Find patterns
- Consider possibilities

Think about our universe. What is in it? (Write ideas on board)

Explain that physicists believe only a tiny fraction of our Universe is made up of regular matter, and there is evidence for tremendous amounts of another type of matter called 'Dark Matter.' But so far, all the evidence is indirect. Astronomers see distorted images or even "double" images of galaxies far away, and they believe this phenomenon is caused by the presence of dark matter**.**

Show a spectacular image from Hubble Space Telescope. (See Print Masters)



Scientists infer from images such as this that dark matter is bending the light from far away galaxies much like the light from the penny and the straw was bent in our experiments today.

The LZ Dark Matter Experiment

The LUX-ZEPLIN (LZ) experiment will be located 4,850 feet (nearly 1 mile) underground at the Sanford Underground Laboratory in Lead, South Dakota. LZ aims to directly detect dark matter interactions with ordinary matter on Earth. If they succeed, it will be one of the greatest scientific discoveries ever.

Exploring the Unseen

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Unit Conclusion

Throughout this unit we've been studying things that are invisible or remote. We've been gathering and reasoning from indirect evidence.

- Do you know of any things that are invisible, but have mass? (*e.g., air and other gasses*)
- What kept the paper towel dry in the paper towel challenge? (*air*)
- What evidence did you have of its presence? (*air bubbles, pressure, etc*)
- If you can't see something, how do you know it is there? (*One can weigh it or see the effect it has on other things. For example, you can feel the molecules in the air when you sit in front of a fan and on your face when you ride a bike.)*
- Did we use any special tools to help us investigate things we could not see during this unit? (*the ability of air to displace water, the marbles in atomic target practice and the black box, as well as the cold surface in no sweat all helped us detect objects we could not see directly*)

We live in a time when many scientific theories have already been 'proven': germs, gravity, etc. But with dark matter, we are alive at a time when this is still a mystery. If we are lucky, dark matter may be detected directly and/or we will learn something entirely new about the Universe soon.

</td></tr>
<tr><td>Terminology and Concepts to Solidify</td><td>

Universe - all of space and everything that is

Galaxy - a giant structure that can contain hundreds of billions of stars

Dark Matter- unseen material that does not emit, reflect, or absorb any type of electromagnetic radiation

Medium-a substance which makes possible the transfer of energy from one location to another (such as air, water)

Refraction- a change of direction that light undergoes when it enters a medium with a different density from the one through which it has been traveling

</td></tr>
<tr><td>Connection to Big Ideas (Phenomena)</td><td>

Structure and properties of matter
Throughout this unit, students developed models that portray matter as particles too small to be seen, yet can be identified based on their properties.

Evidence, models, and explanation
We can use indirect evidence to make inferences about matter we cannot directly observe.

Uncertainty, Collaboration & Scientific Argumentation
Hypotheses/models change with new information and through collaboration with others.

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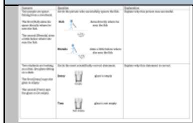
</table>

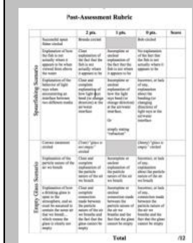
Exploring the Unseen

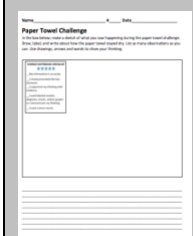
Follow Up/Practice	**Extension penny exploration:** Compile and compare class data and put information into a graph. Students should notice the difference related to height. **Reflection and Refraction of Light: An Introduction for Kids (6 minutes 17 seconds)** This animation explains light reflection and refraction, and how they work with the eye. https://www.youtube.com/watch?v=JRh0CGfX7dQ
Assessment 	Have students explain why spear fishing takes so much practice. What adjustments would they have to make if they were asked to 'spear' the penny in the container with a straw? Why? Encourage students to provide both diagrams and written explanations. This should help determine the how well students can apply what they have studied about refraction of light.

Exploring the Unseen

Lesson 8	Post Assessment and SURF Information (Optional)







Post Assessment

Give students time to complete the unit assessment. (Print from USB)

After the assessment, give students time to visit with others about the scenarios and debrief as scientists would.

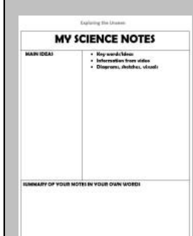
As the facilitator, be prepared to bring the discussion back to the overarching theme- the creativity and ingenuity required to study things that cannot be seen.

Alternative Post Assessment

Video: Keeping Paper Dry Underwater (Revisited) **With Sound Off!**
https://www.youtube.com/watch?v=NHV9cYcdkTY

Have students draw, label, and explain how the paper towel stayed dry. Remind them that they have had lots of experience during this unit thinking like scientists and that they should do their best to communicate their thoughts. Remind students to use the checklist.

There is an additional video on the USB if students completed the alternate exploration with a ping pong ball, or if you wish to check their understanding in a new context.



***This information could be shared at another time and may be easily incorporated into a reading/writing period if necessary.**

Distribute the handout, *My Science Notes*, and discuss how this is to be completed. This is a basic version of Cornell Notes that students may complete while watching the following online videos. There is a section for writing down key words and ideas, sketches, or visuals in the bigger box on the right. On the left is a box for main ideas, which can be completed after the video when they are done taking notes. (Students can also write down key questions in the space on the left.) At the bottom is a box for students to write a summary in their own words.

Introduction to Sanford Underground Research Facility

Staff at the Sanford Underground Research Facility (SURF) in Lead, SD developed this unit. Here is a CNN video about one project, taking place nearly one mile underground.

Unlocking Secrets of the Universe One Mile Below Earth's Surface (2 min 27 seconds), CNN, April 2016
https://www.youtube.com/watch?v=NTmNN5dO5OE

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To introduce the videos, share the following information:

The Sanford Underground Research Facility (SURF) has a new project that is hoping to be among the first to detect proof of dark matter. It is called the LUX-ZEPLIN (LZ) experiment. The name LZ stems from the merger of two dark matter detection experiments: LUX (Large Underground Xenon) and ZEPLIN (ZonEd Proportional scintillation in Liquid Noble gases). The following videos will help explain the original LUX experiment and the hunt for dark matter. Take notes on the main ideas, key words, and other information as given in the footage. Be prepared to write a summary after watching these.

Some of these short videos are packed with information; it can be helpful to show them twice.

Minute Physics: What is Dark Matter? (1 minute, 9 seconds)
July 2011
https://www.youtube.com/watch?v=Af0_vWDfJwQ

Hunting for the WIMPs of the Universe - Science Nation from the National Science Foundation (3 minutes, 19 seconds)

This Is a short, informative video about the LUX experiment at SURF.
https://www.youtube.com/watch?v=sttvBxVKJKE

Also included

SURF overview (on USB) (2 min 32 seconds)
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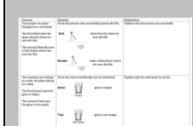
Assessment


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<td>
Post Assessment and Rubric

Print from USB

Use Post Assessment Rubric to evaluate.
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</table>

Exploring the Unseen

Additional Background for the Teacher
Scientists call 'regular' matter baryonic matter, so called because it is made up of particles called baryons. Dark matter is the name given to matter we cannot observe directly, and that appears to be made up of something other than baryons.

Evidence for Dark Matter

Galaxy Cluster Rotation
Fritz Zwicky, a Swiss astronomer, was the first to suspect the existence of dark matter in 1933. He was trying to measure the mass of a galactic cluster (a group of several galaxies) using two different methods. One tried to infer the mass from the speed of the galaxies. The other, the mass from the brightness of the galaxy. When he compared these results with the expected, he realized that there was far more matter in the cluster than what was visible.

Galaxy Rotation
In 1967, another astronomer, Vera Rubin observed that stars within the Andromeda galaxy had higher than expected orbital speeds. The expectation was that stars near the galaxy's center would move faster than those at the edges. However, she observed that stars in the outer 2/3rds or so of the galaxy were orbiting at roughly the same velocity.

Just like kids on a merry-go-round have to hold on to avoid being ejected, galaxies are held together in a spinning galactic cluster by the gravitational force provided by the matter it contains. If there were not enough matter to create this force, the galaxies would simply scatter.

Cosmic Microwave Background (CMB)
Astrophysicists believe the CMB is an image of how "lumpy" the regular matter in the universe was shortly after its formation. These concentrations of matter acted as gravity sinks, drawing more matter to them. However, the lumps seen in the CMB are too small to have had enough gravitational force and attract the matter to see the galaxies and structure we see today. If dark matter accompanied this 'normal' matter, however, these early lumps would have had enough gravitational attraction to create the universe we see today.

Gravitational Lensing
Imagine a stretched bed sheet where you toss a ping-pong ball. The ball will simply roll following the surface of the sheet. But if you drop some heavy object in the middle of the sheet, the ball will still follow the sheet surface but will now move on a curve. Light behaves the same way in space. An empty space, void of any matter is just like a stretched sheet. There, light moves in a straight line. In the presence of a massive object such as a star or a galaxy, the space is deformed and light follows the curvature of the distorted space.

Print Masters

Exploring the Unseen

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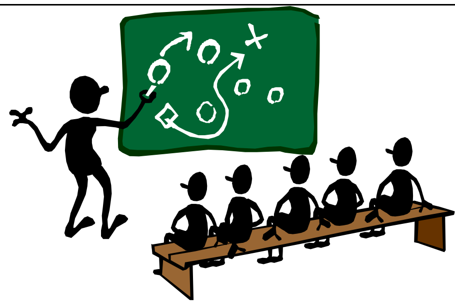
<tr>
<td>
Director</td>
<td>Manages the task and the learning
☑ Review the task with the group
☑ Ensure everyone has a job to do
☑ Ensure everyone has an opportunity to participate
○ Encourage all to share
○ Challenge others to listen
☑ Help the group deal with conflict
☑ Keep discussions on track
☑ Remind the group of ground rules when appropriate</td>
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<tr>
<td>
Materials Manager</td>
<td>Manages the group materials & equipment
☑ Collect necessary materials/equipment
☑ Only take what your group needs
☑ Make sure the work area is kept clean, safe and organized
☑ Return all materials/equipment at the conclusion of the task
☑ Make sure the working area is left clean and tidy</td>
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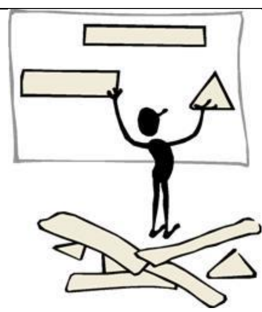
<td>
Data Master</td>
<td>Keeps official record for the group
☑ Keep notes about group discussions
☑ Record data, questions, & conclusions
☑ Use the actual words people use- When in doubt ask for clarification
☑ Be responsible for any written or visual work that needs to be done
☑ Work with the reporter- who will have to present from your notes</td>
</tr>
<tr>
<td>
Reporter</td>
<td>Speaks on behalf of the group
☑ Work with the recorder to make certain you understand notes/diagrams
☑ Make sure you speak for the group (not just yourself)
☑ At the end of the report out, check back with your group members to make certain the important points were covered
☑ Ask questions on behalf of the group</td>
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Name______________________________ #_____ Date___________________

Paper Towel Challenge

In the box below; make a sketch of what you saw happening during the paper towel challenge. Draw, label, and write about how the paper towel stayed dry. List as many observations as you can. Use drawings, arrows, and words to show your thinking.

SCIENCE NOTEBOOK CHECKLIST

★★★★★

__My information is accurate.

__I clearly presented the key elements.

__I supported my thinking with evidence.

__I used labeled models, diagrams, charts, and/or graphs to communicate my thinking.

__I used science words.

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Name_______________________________ #_____ Date____________________

Ping Pong Ball Challenge

In the box below; make a sketch of what you saw happening during the paper towel challenge. Draw, label, and write about how the paper towel stayed dry. List as many observations as you can. Use drawings, arrows, and words to show your thinking.

SCIENCE NOTEBOOK CHECKLIST

★★★★★

__My information is accurate.

__I clearly presented the key elements.

__I supported my thinking with evidence.

__I used labeled models, diagrams, charts, and/or graphs to communicate my thinking.

__I used science words.

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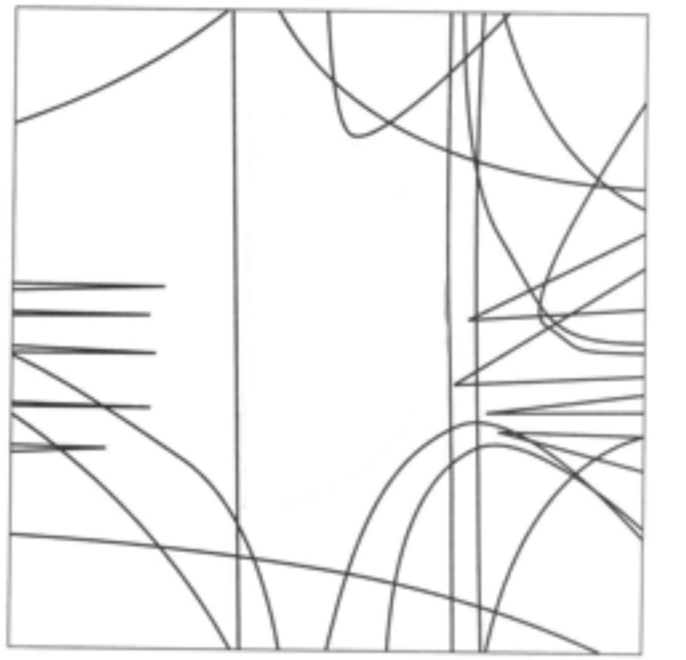
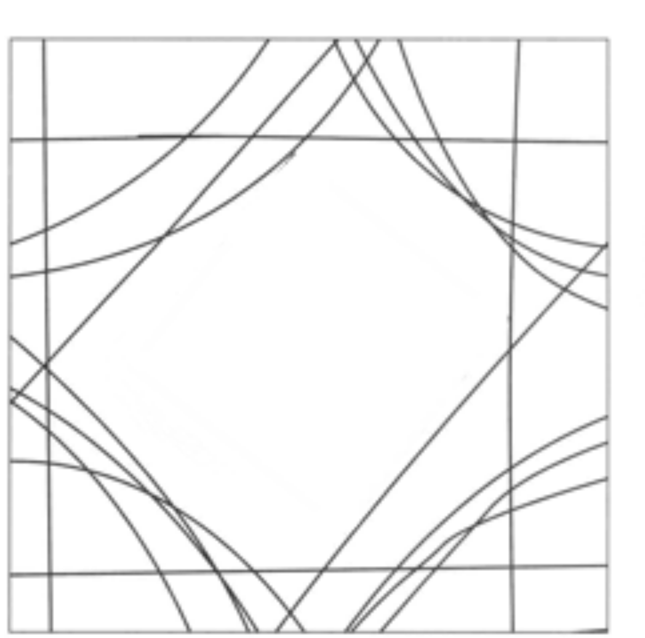
Atomic Target Practice Sample Data





Exploring the Unseen

Inference Photos

Exploring the Unseen

Inference Photos

INFERENCE/OBSERVATION CHART

In your groups, discuss the photographs. What can you observe?
What inferences can you make based on those observations?
Record your thinking below.

Inference	Observation/Evidence

Group Work Rubric			
	1 = Below Basic	**2 = Basic**	**3 = Proficient**
Task Completion	Group had great difficulty creating a product.	Group created an end product that included some required components.	Group successfully created a fully functional product containing all required components.
Cooperative Group Work	Group had trouble working together as a group.	Group had some challenges working together but resolved enough to complete the task.	Group worked cooperatively together to successfully complete the task
Communication	Group communicated limited observations with the whole class.	Group communicated some general observations, ideas, etc. with the whole class.	Group successfully communicated thorough observations, ideas, etc. with the class.

SCIENCE NOTEBOOK RUBRIC

	1 Below Basic	2 Basic	3 Proficient	4 Advanced
Science Content	Inaccurate; Based on misconceptions about ideas in science	Mostly accurate; Connections to big ideas are not evident	Accurate; Connected to big ideas in science	Elaborate; Connected to big ideas and other related science content, real-world applications or other subject areas
Communication and Organization Of Big Ideas	Ideas may be focused on isolated details rather than main ideas	Some main elements are presented	Main elements are clearly presented	Connections to main elements are presented
	Ideas are presented in an order that distracts from clarity	Ideas are not presented in an appropriate order	Ideas are presented in an appropriate order	Ideas are presented in an effective order with logical connections
	Ideas may not be related to evidence or may contain minimal information	Some ideas are supported by evidence	Ideas are supported by evidence	Ideas are clearly supported by evidence
	Conclusions are missing or unrelated	Conclusions do not follow from ideas information presented	Appropriate conclusions are based upon evidence presented	All conclusions are based upon evidence presented and correctly inferred
Presentation	Attempts to express ideas in words or pictures. May need guidance to complete journal entry	Some appropriate use of labeled models, diagrams, charts, and/or graphs and text	Effective use of labeled models, diagrams, charts, and/or graphs and text	Labeled models, diagrams charts, and/or graphs and text are integrated to tell a complete story
Use of Science Language	Inaccurate use of science language; uses vague language or terminology or lacking science words	Uses a combination of appropriate science language and general everyday language	Consistent use of appropriate science language and terminology	Precise and clear use of scientific language and terminology that enhance the communication

Exploring the Unseen

Planning an Investigation

Variables That Could Change

Things That Could Be Measured or Observed

Design Your Own Experiment
Question:
Variable that will change (you may only change one part of your experiment):
Variables that stay the same (control):
Materials:
Data to collect:
What will be observed:
Hypothesis (an idea based on what you know that has not yet been tested):

Hubble Telescope Photographs: Galaxies

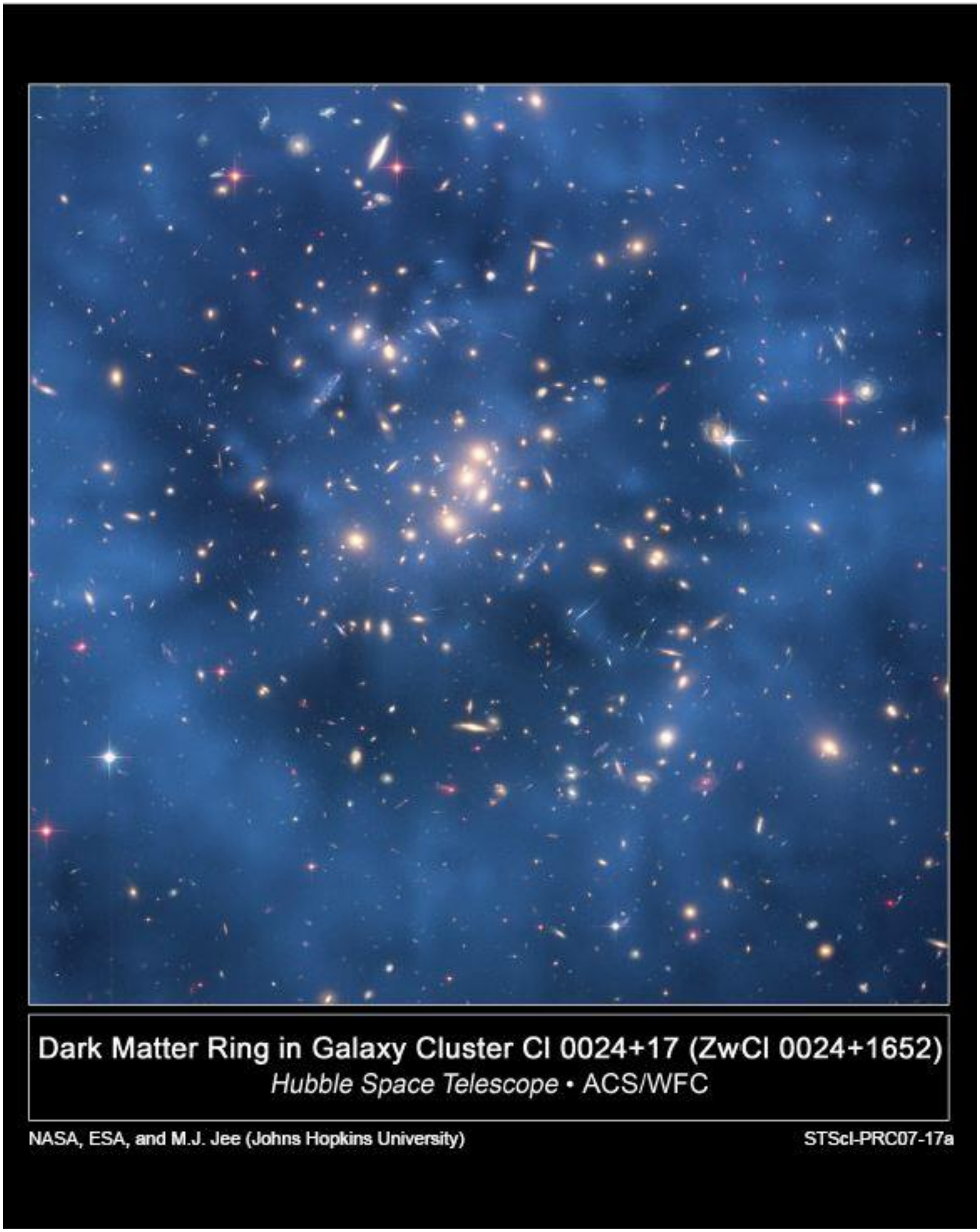
Andromeda Galaxy

Hubble Telescope Photographs: Celestial Bodies

The "Celestial Snow Angel" is a star formation region in the constellation Cygnus about 2,000 light years from Earth in an isolated area of the Milky Way.

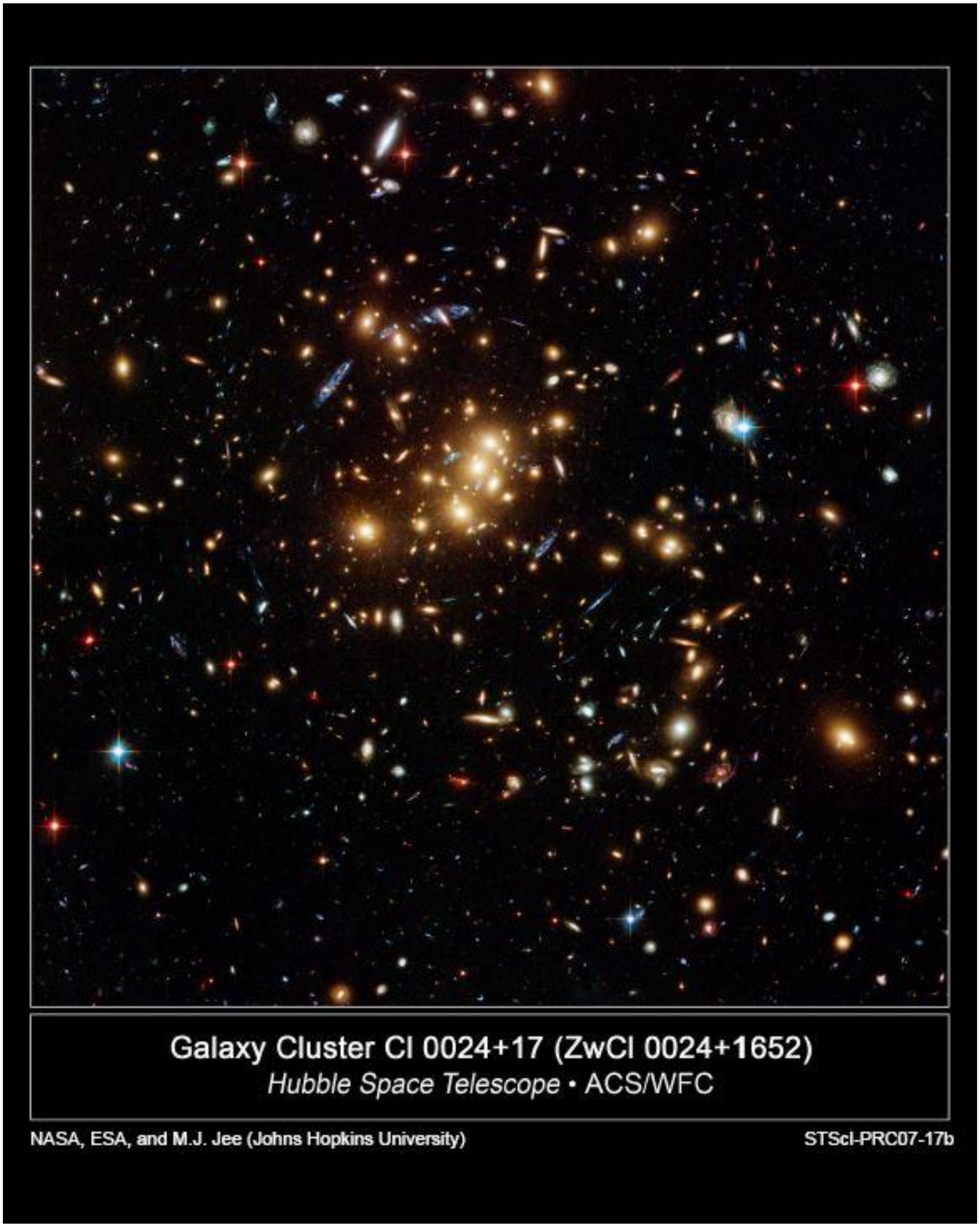
The gaseous outer layers of a Sun-like star glow in space after being expelled as the star reached the end of its life.

Hubble Telescope Photograph: Dark Matter Ring in Galaxy Cluster



Exploring the Unseen

Hubble Telescope Photograph: Galaxy Clusters



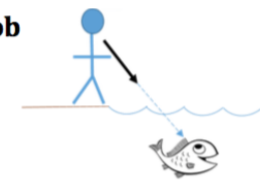
Post-Assessment Rubric

		2 pts.	1 pts.	0 pts.	Score
Spearfishing Scenario	Successful spear fisher circled	Brenda circled		Bob circled	
	Explanation of how the fish is not actually where it appears to be when viewed from above the water	Clear explanation of the fact that the fish is not actually where it appears to be	Incomplete or unclear explanation of the fact that the fish is not where it appears to be	No explanation of the fact that the fish is not actually where it appears to be	
	Explanation of the behavior of light rays when encountering an interface between two different media	Clear and complete explanation of how light rays bend (or change direction) at the air/water interface	Incomplete or unclear explanation of how the light rays bend (or change direction) at the air/water interface, Or simply stating "refraction"	Incorrect, or lack of any, explanation about the bending (or changing direction) of light rays at the air/water interface	
Empty Glass Scenario	Correct statement circled	(Tom) "*glass is not empty*" circled		(Jenny) "*glass is empty*" circled	
	Explanation of the particle nature of the air we breath	Clear and complete explanation of the particle nature of the air we breath	Incomplete or unclear explanation of the particle nature of the air we breath	Incorrect, or lack of any, explanation about the particle nature of the air we breath	
	Explanation of how a drinking glass is open to the atmosphere, and so must be assumed to contain the same air that we breath… which means the glass is clearly not empty	Clear and complete connection made between the particle nature of the air we breathe and the fact that the glass cannot be empty	Incomplete or unclear connection made between the particle nature of the air we breathe and the fact that the glass cannot be empty	Incorrect, or lack of any, connection made between the particle nature of the air we breathe and the fact that the glass cannot be empty	

Total **/12**

/Post-Assessment

Answer the following. You may include illustrations to help with your explanations.

Scenario	Question	Explanation
Two people are spear-fishing from a riverbank. The first (Bob) aims his spear directly where he sees the fish. The second (Brenda) aims a little below where she sees the fish.	Circle the person who successfully spears the fish. **Bob**  Aims directly where he sees the fish **Brenda**  Aims a little below where she sees the fish	Explain why this person was successful.
Two students are looking at a clear, dry glass sitting on a desk. The first (Jenny) says the glass is empty. The second (Tom) says the glass is not empty.	Circle the most scientifically correct statement. **Jenny**  glass is empty **Tom**  glass is not empty	Explain why this statement is correct.

MY SCIENCE NOTES

MAIN IDEAS	• Key words/Ideas • Information from video • Diagrams, sketches, visuals

SUMMARY OF YOUR NOTES IN YOUR OWN WORDS

SCIENCE NOTEBOOK OVERVIEW

Scientists use journals or notebooks to record their ideas, questions, and models in a variety of ways. Like scientists, students will use their notebooks to record their thinking throughout the unit. The science notebook is a special place where students may record data, make observations, create graphs, use charts, attach information, draw sketches, label diagrams, keep handouts, etc. Teachers may also want to take advantage of the notebooks to enhance the science content focus with literacy skills (restate main idea/detail, write a poem about your science topic sharing your learning, write a letter from the point of view of an element, etc.) Students enjoy having a special booklet for science.

Science notebooks may be created by making copies of the following templates along with the unit handouts and putting them into folded or stapled booklets. Multiple copies of specific pages can be made. Notebooks may be made simply using folded construction paper as a cover (9" x 18") with blank 8 ½" x 11" paper inside. (A science notebook may also be a spiral notebook or composition book that is set up during the first days of school with numbered pages containing a Table of Contents, Glossary, and/or Index.) If the templates are used as a packet or booklet to give to students, the Science Notebook Rubric may be included inside the front cover so students will understand expectations. Make sure the science notebook is large enough to handle attaching handouts with glue stick or tape. Teachers may want to read through the unit to see which sheets they want to attach in the booklet, and which they might collect separately or send as homework. Some teachers use one booklet per unit; others use one for the whole year.

Note: There is only one general Science Notebook page for notes and drawings (after Table of Contents). This page has a checklist included on the document to remind students of expectations for entries. Teachers will want to run several copies for students to use (2 per lesson minimum is recommended). Alternatively, checklists are available at the end of the document if teachers already have a science notebook system in place. If Science Notebooks are only used for this particular unit, teachers may wish to choose between the Glossary and the Index.

SCIENCE NOTEBOOK

Name: ______________________

Teacher: ____________________

SANFORD UNDERGROUND RESEARCH FACILITY

SCIENCE NOTEBOOK RUBRIC

	1 Below Basic	2 Basic	3 Proficient	4 Advanced
Science Content	Inaccurate; Based on misconceptions about ideas in science	Mostly accurate; Connections to big ideas are not evident	Accurate; Connected to big ideas in science	Elaborate; Connected to big ideas and other related science content, real-world applications, or other subject areas
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	Ideas are presented in an order that distracts from clarity	Ideas are not presented in an appropriate order	Ideas are presented in an appropriate order	Ideas are presented in an effective order with logical connections
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Presentation	Attempts to express ideas in words or pictures. May need guidance to complete journal entry	Some appropriate use of labeled models, diagrams, charts, and/or graphs and text	Effective use of labeled models, diagrams, charts, and/or graphs and text	Labeled models, diagrams charts, and/or graphs and text are integrated to tell a complete story
Use of Science Language	Inaccurate use of science language; uses vague language or terminology or lacking science words	Uses a combination of appropriate science language and general everyday language	Consistent use of appropriate science language and terminology	Precise and clear use of scientific language and terminology that enhance the communication

Table of Contents

Page(s)	Title/Topic	Date(s)

Exploring the Unseen

Date______________________________ Page ________

SCIENCE NOTEBOOK CHECKLIST

★★★★★

__My information is accurate.

__I clearly presented the key elements.

__I supported my thinking with evidence.

__I used labeled models, diagrams, charts, and/or graphs to communicate my thinking.

__I used science words.

SCIENCE NOTEBOOK PROCESS

My question: ____(Question)

Today I/we want to find out __________________________________ (Problem)

I think ____________________ will happen *because*______________ (Prediction)

I noticed/observed____ (Observation)

I claim ____*because*

____(Claims & Evidence)

Today I learned ____(Conclusion)

I wonder ____(Reflection)

Questions I have now are ______________________(Next Steps/New Questions)

SCIENCE NOTEBOOK CHECKLIST

Name____________________ **SCIENCE NOTEBOOK CHECKLIST** __My information is accurate. __I clearly presented the key elements. __I supported my thinking with evidence. __I used labeled models, diagrams, charts, and/or graphs to communicate my thinking.	**Name____________________** **SCIENCE NOTEBOOK CHECKLIST** __My information is accurate. __I clearly presented the key elements. __I supported my thinking with evidence. __I used labeled models, diagrams, charts, and/or graphs to communicate my thinking.
Name____________________ **SCIENCE NOTEBOOK CHECKLIST** __My information is accurate. __I clearly presented the key elements. __I supported my thinking with evidence. __I used labeled models, diagrams, charts, and/or graphs to communicate my thinking. __I used science words.	**Name____________________** **SCIENCE NOTEBOOK CHECKLIST** __My information is accurate. __I clearly presented the key elements. __I supported my thinking with evidence. __I used labeled models, diagrams, charts, and/or graphs to communicate my thinking. __I used science words.