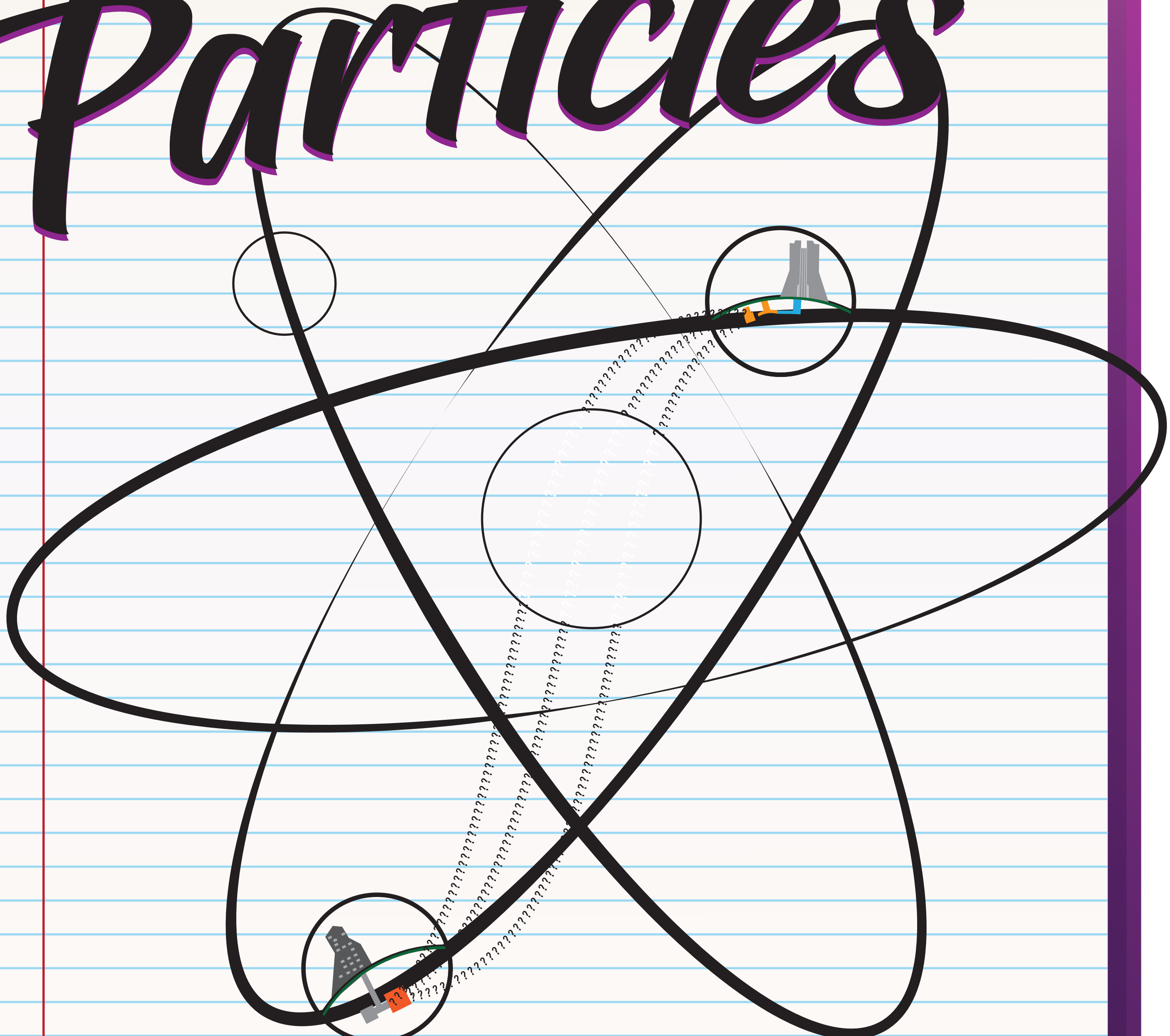
Ghost Particles



Education and Outreach

3 - 5

Curriculum Unit

Ghost Particles

"Structure and Properties of Matter"

Crosscutting Concept Emphasis: Scale, Proportion, Quantity

Lesson #	Lesson Title	Suggested Time
1	A Salty Topic	55 minutes
2	The Size of Things	55 minutes
3	Now you See It…	55 minutes
4	…Now You Don't	55 minutes
5	What's Up with Air?	55 minutes
6	Making Atoms 'Visible'	55 minutes
7	A Ghost Particle *	55 minutes

*This lesson can be replaced or supplemented with a visit by an E&O team member from SURF.

Ghost Particles (3-5)

Driving Questions that students address over the course of the unit: What happens to matter when it becomes too small to see? Is it still matter? Can we still attribute properties to it? How do we know it exists?

Anchoring Phenomenon: A solid (salt) mixing with a liquid (water) and seeming to disappear.

Ghost Particles

Structure and Properties of Matter

Matter and Its Interactions (PS1) is a core idea that underlies our understanding of the physical world around us. In the early elementary grades (2nd grade performance expectations), students learn that matter can be in a solid or liquid state, and that the state can change by raising or lowering the temperature. By the end of 5th grade, students have learned that matter is made of particles too small to see, one example being matter in a gaseous state (e.g., air). By the end of middle school, they should be able to model liquids and gases as a collection of particles called atoms or molecules, and use these models to predict changes of state that occur when temperature or pressure is changed.

Tied very closely to this DCI is the crosscutting concept (CCC) Scale, Proportion and Quantity. By the end of 5th grade, students should recognize that natural objects and observable phenomena exist from the very small to the immensely large. By the end of middle school, they should understand the use of models for studying systems that are too large or too small to observe directly, and understand that phenomena observed at one scale may not be observable at another scale. It's not until high school that students are expected to fully master an understanding that indirect evidence is used to study systems that are too small, too large, too fast or too slow to observe directly.

This unit focuses on 5th grade standards addressing the Disciplinary Core Idea (DCI), Structure and Properties of Matter (PS1.A), particularly, the particle nature of matter. The unit asks the questions 'Are particles that are too small to see still matter?' and 'If something is too small to see, how do we know it exists?' The unit connects to the (SURF) Underground Research Facility through the Deep Underground Neutrino Experiment (DUNE), planned for construction beginning in 2020. The DUNE experiment will be studying neutrinos, the most abundant 'subatomic' particle known. A neutrino is so incredibly tiny that it passes right through most matter without leaving a trace.

In Lesson 1 –A Salty Topic - students review the concept that objects have properties that can be either observable or measurable. This gives the teacher the opportunity to assess prior knowledge on the topic (without introducing the term matter). Then students are introduced to the unit phenomenon, the apparent disappearance of salt when added to water, an everyday phenomenon for which they most likely lack a deep understanding. ***(5-PS1-3)***

In Lesson 2 – The Size of Things – students are introduced, or reintroduced, to the metric system, then apply their math skills as they explore sizes of things in the classroom and down to the limits of their vision. They use handheld microscopes to take the next step smaller. How small an object can they see with the tools they have? What tools could take them further? ***(5-PS1-1, 5-PS1-3)***

Lesson 3 – Now You See It… - gives students the opportunity to observe and measure properties of salt before and after grinding. They learn that the weight of a quantity of salt stays the same even when ground almost too small to be seen. ***(5-PS1-1; 5-PS1-2; 5-PS1-3)***

In Lesson 4 - …Now You Don't! - students plan and carry out an investigation to collect evidence about what happens to the salt when it is added to water. They use evidence and reasoning to support a claim about what happened to the salt and whether or not the dissolved salt is still matter. ***(5-PS1-1; 5-PS1-2; 5-PS1-3)***

In Lesson 5 – What's Up with Air? – students explore a state of matter that they cannot see, gasses. They do an experiment to show that air has weight and takes up space, thus is matter. But why can't we see it? Whatever air is, it must be too small to see. They are introduced to the concept of atoms and molecules. ***(5-PS-1-1; 5-PS1-2; 5-PS1-3)***

In Lesson 6 – Making Atoms 'Visible' – students begin to synthesize what they learned in Lesson 1 about the size of things with what they learned in Lesson 2&3 about the particle nature of matter. After being introduced to the nanoscale – the size that applies to atoms – students construct a detector that can detect invisible particles in the air, make observations, and develop explanations. ***(5-PS-1-1; 5-PS3-2)***

Finally, in Lesson 7 - A Ghost Particle – students learn about the tiniest of particles, the neutrino, which is also the most abundant particle in the universe. They build models of an atom and use scale, proportion and quantity to construct an explanation for why neutrinos go right through the earth, are so very hard to detect and need very large detectors. They will then connect to neutrino detectors at SURF. ***(5-PS-1-1; 5-PS1-2; 5-PS1-3)***

Driving Questions Used in Ghost Particles

LESSON	DRIVING QUESTIONS	WHAT STUDENTS FIGURE OUT OR LEARN
LESSON 1 A Salty Topic	L: In science, what is meant by the properties of objects?	An object can be described by its properties, which could be observable with the senses or measurable with tools.
	E: When we mix salt with water, how do the properties change?	Salt and water have distinct properties; when mixed and stirred, the salt seems to disappear, leaving something with many of the properties of water.
	S: What is happening when the salt is mixed with water? Can we draw a model of the salt+water system? What questions do we still have?	We may have some ideas about what could have happened to the salt, but we have many questions and need to learn more.
LESSON 2 The Size of Things	L: What is the metric system?	The metric system is universally used in science for measurements, including length, volume and weight.
	E: How can we use the property of size to characterize objects we observe? What patterns do we observe? How can we use technology to see objects too small to observe with our eyes?	The metric system gives us standard units of size that can be used to characterize objects we observe. As we explore smaller and smaller objects, we might reach the limits of our eyes and may need tools such as microscopes or hand lenses to explore further.
	S: What are powers of 10 and how do they help us describe the size of objects?	We can use powers of 10 as a shorthand to describe the size of objects we observe.

LESSON 3 Now You See It…	L: What is matter? Are all the objects we examined in Lesson 2 matter?	Matter is defined as anything that has weight (mass) and takes up space (has volume). All the object we examined in Lesson 2 can be described as matter.
	E-A: How do the properties of salt change with size?	Grains of salt have a variety of shapes and sizes which can be observed and measured. If we crush a grain of salt we get many more smaller grains with a variety of shapes and sizes.
	S-A: Are all the properties of salt the same when you crush it or do some of them change?	Some properties of salt may change when you crush it (e.g., size) and some may stay the same (e.g., color, shape…).
	E-B: Does the weight of salt change when it is crushed into smaller pieces?	We can conduct an investigation to determine whether the weight of a quantity of salt is different before and after crushing.
	S-B: Is salt matter? What have we learned so far about salt that could help explain what happens when it is mixed with water?	If we do our investigation carefully, we find that the weight does not depend on how much we have crushed the salt.
LESSON 4 …Now You Don't!	L: What investigations could give us new evidence about what happens when salt is added to water?	Students brainstorm ideas for possible investigations that could help elucidate what is happening when water is added to salt.
	E: How will we carry out our planned investigation to learn more about the salt + water system?	After the class comes to consensus as to what data will give them needed evidence, groups will plan their investigation and carry it out.
	S: How does the data we collected and analyzed help explain what happens when the salt is stirred into the water? Are there similarities with a simple model of dots printed on a piece of paper?	Our investigation shows us that the weight of the salt + water system is equal to the weight of the salt plus the weight of the water. The volume of the water increases when salt is added

		but is not equal to the total volume of the two individually. The salt must still be there somewhere. Maybe it is spread out in the water so that it can't be seen, like the dots on the paper.
LESSON 5 What's Up with Air?	L: What happens when heat is added to water?	When heat is added to water, it appears to disappear into the air.
	E: What is air? Is air matter?	We plan and conduct investigations to gather evidence for whether air has weight and takes up space so that we can decide whether or not it is matter.
	S: How does a theory that all matter is made up of particles (atoms) that are too small to see help explain natural phenomena such as salt 'dissolving' in water, water boiling and properties of air?	A model that matter is made up of atoms too small to see can explain many of the phenomena we have explored about salt (a solid), water (a liquid) and air (a gas).
LESSON 6 Making Atoms 'Visible'	L: How small is an atom?	Even an object that is almost too small to see (a speck of dust) contains trillions of atoms, so atoms are very, very small. We learn that they are on the order of a nanometer and can be made visible with the most sensitive microscopes.
	E: How can we use indirect evidence to show that air is made up of atoms and molecules?	We can build a simple detector that exhibits changes when atoms that we know have static charge are nearby.
	S: How does the behavior of the electroscope give us evidence that a rod is 'emitting' special, invisible particles?	Observations of an unknown object with our detector can give evidence for what kind of invisible particles are 'emitted' by the object.

LESSON 7 A Ghost Particle	How small is an atom, really?	We learn about the parts of an atom and how much smaller the parts are than the atom itself.
	How can we build a mental model that helps us to understand the smallness of an atom and its parts?	We scale the atom and its parts up powers of 10 to sizes that we can model in the classroom.
	Are there any objects smaller than the nucleus and electron in an atom? How small is a neutrino and is it matter?	We learn about neutrinos, the smallest (and most abundant) matter particle known to exist in the universe. We compare the size of the neutrino to an atom. We learn about the experiments at SURF designed to learn more about neutrinos.

Ghost Particles

Standards Addressed in the Unit

Performance Expectations		**Lessons**
5-PS1-1	Develop a model to describe that matter is made of particles too small to be seen. (SEP: 2; DCI: PS1.A; CCC: Scale, Proportion & Quantity)	2,3,4,5, 6
5-PS1-2	Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. (SEP: 5; DCI: PS1.A, PS1.B; CCC: Scale, Proportion & Quantity)	3,4,5
5-PS1-3	Make observations and measurements to identify materials based on their properties. (SEP: 4 DCI: PS1.A CCC: Scale, Proportion & Quantity)	1,2,3,4, 5,6
3-PS2-3	Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other. (SEP: 1; DCI: PS2.B; CCC: Cause and Effect)	6
3-5-ETS1-1	Define a simple design problem reflecting a need or want that includes specific criteria for success and constraints on materials, time or cost.	6,7

Ghost Particles
Three-Dimensional Learning Matrix

Lesson	Disciplinary Core Idea	Science and Engineering Practice	Crosscutting Concept
1 Matter: A Salty Topic	Measurements of a variety of properties can be used to identify materials (5-PS1-3)	Asking questions and defining problems Developing and using models	Structure and function
2 The Size of Things	Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. (5-PS1-1)	Asking questions and defining problems	Scale, proportion and quantity
	Measurements of a variety of properties can be used to identify materials (5-PS1-3)	Developing and using models	Patterns
3 Now You See It…	Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. (5-PS1-1)	Planning and carrying out investigations	Scale, proportion and quantity
	The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. No matter what reaction or changes in properties occurs, the total weight of the substances does not change. (5-PS1-2)	Analyzing and interpreting data	
	Measurements of a variety of properties can be used to identify materials (5-PS1-3)	Developing and using models	

4 … Now You Don't	Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. (5-PS1-1)	Planning and carrying out investigations	Scale, proportion and quantity
	The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. No matter what reaction or changes in properties occurs, the total weight of the substances does not change. (5-PS1-2)	Analyzing and interpreting data	
	Measurements of a variety of properties can be used to identify materials (5-PS1-3)	Developing and using models	
5 What's Up with Air?	Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations. (5-PS1-1)	Planning and carrying out investigations	Scale, proportion and quantity
	The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. No matter what reaction or changes in properties occurs, the total weight of the substances does not change. (5-PS1-2)	Analyzing and interpreting data	
	Measurements of a variety of properties can be used to identify materials (5-PS1-3)	Developing and using models	
	Matter of any type can be subdivided into particles that	Constructing explanations	Cause and effect

6 Making Atoms 'Visible'	are too small to see, but even then the matter still exists and can be detected by other means. (5-PS1-1)	and developing solutions	Scale, proportion and quantity
	Electric forces and magnetic forces are different aspects of a single electromagnetic interaction. Electric forces can be attractive or repulsive, depending on the relative sign of the electric charges involved. Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact. (3-PS3-2).	Developing and using models	Influence of science and technology on society and the natural world
7 A Ghost Particle	Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means.(5-PS1-1)	Developing and using models	Scale, proportion and quantity
	Over time, people's needs and wants change, as do their demands for new and improved technologies. Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. (3-5 ETS 3-2)	Obtaining, evaluating and communicating information	Influence of science and technology on society and the natural world

Science Content Developed Throughout Ghost Particles

Terminology or concepts in bold are defined in the vocabulary section below and in student language in the individual lessons in which they are introduced

LESSON 1 – A Salty Topic

The **macroscopic** world of objects is what students experience every day. In earlier grades, students explore the **physical properties** of objects in the form of solids or liquids. Physical properties can be **measurable** or **observable** with the senses.

LESSON 2 – The Size of Things

The size of an object is one measurable physical property. Scientists use the **metric system** as a standard unit of measurement. Using the metric system, students will review the units of size for macroscopic objects in our world (**meter**, **decimeter**, **centimeter,** and **millimeter**) and then use and/or learn about tools (**magnifying glass (hand lens)** and **microscope**) to start exploring objects at the **micrometer** scale. They review the mathematical concept of **powers of 10**. (Scientists refer to this as orders of magnitude.)

LESSON 3 – Now You See It…

The term **matter** refers to the substance that makes up all the objects in the world around us, those things that have physical properties that can be measured or observed. In elementary textbooks, matter is defined as anything that has **mass** and takes up space (has **volume**), two of the measurable properties. In the elementary standards, students are expected to understand and measure the **weight** of an object rather than its mass. (The weight depends on the gravitational pull on an object, so on Earth the weight and mass are equivalent, but not if you went to Mars!)

LESSON 4 – …Now You Don't

When mixing two substances, the total amount of matter in the mixture is conserved. This is called the **Law of Conservation of Mass** (since the measure of the amount of matter is its mass (or weight)). In other words, matter cannot be created or destroyed (under normal conditions). The volume may not stay the same, as students will learn in Lesson 5.

LESSON 5 – What's Up with Air?

After investigating the macroscopic world, students will begin to study the properties of matter they cannot see, the **microscopic** world. By introducing the concept that matter is made up of **atoms** too small to see, students can model three **states of matter - solid** , **liquid** and **gas**. A **phase change** is the scientific terminology for when a substance is changed from one state to another due to heating or cooling. Some examples are **evaporation –** changing from liquid to a gas phase, and **condensation –** changing from gas to liquid phase.

Atoms are the basic building blocks of the macroscopic world, and there are approximately 100 different types (**elements**). All atoms are too small to be seen with the naked eye. Sometimes atoms combine to make larger structures called **molecules**. These are also too small to be seen with the naked eye. Air contains both atoms and molecules. There are about 10,000,000,000,000,000,000 (19 zeros!) atoms or molecules in 1 cubic centimeter of air. In a solid or a liquid there are so many more atoms bound together that the system becomes visible. For example, in a speck of dust 0.01 millimeter in size, there are approximately a trillion (1,000,000,000,000) (12 zeros) atoms. If you were to pack a cubic centimeter of air with dust particles you might have a billion dust particles, or 1,000,000,000,000,000,000,000 (21 zeros!) and you can only see them in a bright sunbeam. In order to deal with the very large and very small numbers necessary to discuss atoms, students are introduced to **scientific notation**.

LESSON 6 – Making Atoms 'Visible'

Technology can be used to extend the limitations of the human eye. An optical microscope makes matter visible at the scale of a **micrometer (**1/millionth of a meter) **(4)** The most sensitive instrument to study very small objects is a special microscope called a **scanning electron microscope (SEM). (4)** An SEM can image at the **nanometer (**1/billionth of a meter) **(4)** scale, and make atoms visible. SEMs are large and very expensive so are not generally available.

More than 100 years ago, scientists discovered that an atom isn't just a solid sphere 1/billionth of a meter in diameter; rather it is consists of smaller **particles (4)** which cannot be seen with even the most sensitive microscope**.** Scientists detect particles smaller than atoms using **indirect evidence (4)**, making **inferences (4)** about what they cannot see to develop mental models*. For example, many observations - including the inflation and shape of a balloon; the effects of air on larger particles or objects (e.g., leaves in wind, dust suspended in air); and the appearance of visible scale water droplets in fog - can be explained with a model that gases (air, steam) are made from particles that are too small to see and are moving freely around in space.

One particle is an **electron (4)** The electrons have a negative **electric charge (4)** and can be removed from atoms relatively easily. This leads to many practical applications such as electricity. Students will use **static electricity (4)** to build a device called an **electroscope (4)** to detect atoms. An electroscope is an example of a detector that uses properties of particles such as atoms to understand the structure and function of the particles.

The negatively charged electrons in an atom are attracted through the **electromagnetic force (5)** to the **nucleus (5)** of the atom, which has a positive electric charge. The electrons orbit around the nucleus, similar to planets around the Sun. The orbits for electrons are not well defined, however. One can never predict exactly where an electron will be. The size of the atom is defined by the furthest orbits of the electrons.

Ghost Particles (5) is a nickname given to **neutrinos (5)**, which based on our current understanding is the smallest and most abundant particle in the universe. Somewhere buried deep inside the nucleus of an atom are the elusive neutrinos that are studied at the Sanford Underground Research Facility. For more information about Sanford Underground Research Facility, visit www.sanfordlab.org.

Definitions of Science Terms Used in Ghost Particles

Lesson 1

Macroscopic - physical objects that are measurable and can be seen by the naked eye

Physical properties – The physical properties of an object or substance are observable or measurable characteristics that make it unique.

Measurable properties – A measurable property is one that can be measured with a tool. Examples of measurable physical properties are weight (mass), length, volume, density, etc.

Observable properties – An observable property is one in which the five senses are used to get information about an object. Some examples of observable physical properties are color, odor, taste, state (solid, liquid), etc.

Lesson 2

Meter –the basic unit of distance in the International System of Units (SI), the world's standardized system of measurement, referred to as the metric system.

More than 200 years ago, one meter was defined as one ten-millionth of the distance from the Equator to the North Pole. The definition of a meter has changed since 1791. Today, a meter is defined using the speed of light, a universal constant.

Decimeter –a metric unit of length, equal to one tenth of a meter

Centimeter - a metric unit of length, equal to one hundredth of a meter

Millimeter- a metric unit of length, equal to one thousandth of a meter

Hand lens (magnifying glass) –a lens that produces an enlarged image, typically set in a frame with a handle and used to examine small or finely detailed things such as fingerprints, stamps, and fine print

Microscope – an instrument used to see objects that are too small to be seen by the naked eye

Powers of 10 - In mathematics, a power of 10 is ten multiplied by itself a certain number of times.

Lesson 3

Matter– the substance of which all material is made. Matter has physical properties which can be measured, such as mass, volume, density, and qualitative properties which can be experienced through the senses, such as taste, smell and color.

Mass –an intrinsic property of an object, defined as the amount of matter contained in the object; it does not depend on its volume, or position in space, for instance.

Volume – the quantity of three-dimensional space occupied by a liquid, solid, or gas. Common units used to express volume include liters, cubic meters, gallons, milliliters, teaspoons, and ounces, though many other units exist.

Weight –the measure of the force of gravity on an object. Weight is different from mass. The mass of an object will never change, but the weight of an item can change based on its location.

For example, a person may weigh 100 pounds on Earth, but in outer space, the gravitational force would be so low that they would feel ‘weightless’. They would have the same amount of mass, though. While we are on Earth, we can use weight and mass interchangeably.

Lesson 4

Law of Conservation of Mass –states that matter cannot be created or destroyed. The amount of matter (mass or weight) will stay the same whether it is mixed with something else or otherwise changed.

Lesson 5

Atom –the building blocks of the matter that our world is made of. Atoms are too small to be seen in regular microscopes.

States (phases) of Matter – Matter can come in one of several states, also called phases. The ones we are most familiar with are solids, liquids and gases.

Solid – In a solid, the atoms are attracted to each other and stick together to become a substance that holds its shape without a container.

Liquid – In a liquid, the atoms or molecules are close together but not too close; a liquid takes the shape of its container.

Gas - In a gas, the atoms and molecules are far apart and invisible.

Evaporation –the transition between liquid and gas phase

Condensation - the transition between gas and liquid phase

Molecule –a combination of one or more types of atoms. For example, water has two hydrogen atoms and one oxygen atom in it. We write water as H_2O in scientific shorthand.

Lesson 6

Scientific Notation - a mathematical shorthand for writing very large or very small numbers by writing it as a number between 1 and 10 multiplied by a power of 10, written as $10^{\wedge power.}$ For example, $1000 = 10^3$ in scientific notation. For numbers less than 1, the superscript is negative. For example, 1 mm = 0.001 meters = 10^{-3} meters.

Micrometer –a metric unit of length, equal to one millionth of a meter, 10^{-6}

Scanning Electron Microscope (SEM) - a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing signals that contain information about the surface topography and composition of the sample. A SEM can image individual atoms in a solid.

Nanometer –a metric unit of length, equal to one billionth of a meter, 10^{-9}

Particle - tiny bits of microscopic matter that make up everything in the universe. There are many different types of particles, with different particle sizes and properties.

Subatomic particle – Particles that are smaller than an atom are called subatomic particles. Atoms are made up of three types of subatomic particles – electrons, protons and neutrons.

Inference –a conclusion reached on the basis of evidence and reasoning

Indirect Evidence –a claim about an object or phenomenon that is based on inference

Electron –a stable subatomic particle with a charge of negative electricity, found in all atoms and acting as the primary carrier of electricity in solids

Electric Charge –a fundamental property of particles. Charge can be either negative, positive or neutral. Electric charge is associated with the electromagnetic force, and like magnets, two particles with electric charges of opposite signs are attracted to each other and two particles with electric charges of like signs are repelled.

Static electric charge (static electricity) –an imbalance of electric charges within or on the surface of a material. The charge remains until it is able to move away by means of an electric current or electrical discharge.

Electroscope –an early scientific instrument used to detect the presence of electric charge on a body

<u>Lesson 7</u>

Atomic Nucleus –the very dense central region of an atom, with positive charge

Neutrino –subatomic particles related to electrons. Neutrinos have no electric charge and a very small mass, so small that scientists have not been able to measure it (yet).

Ghost Particle –a commonly used term for a neutrino because it travels right through matter and is very difficult to detect

3-Dimensional Learning Strategies Featured in Ghost Particles

Making Thinking Visible in Science (from Almarode, et al. *Visible Learning for Science*)

Education research has shown that there are three stages of learning students must progress through in order to gain conceptual understanding of a topic: Surface, Deep and Transfer:

1. Surface learning is the initial acquisition of content knowledge, followed by associated procedural skills to consolidate this learning. Surface learning includes leveraging prior knowledge, direct instruction, vocabulary, observation and experimentation, and other means. Surface learning can be made visible in a variety of ways, including science notebooks and exit cards.
2. Deep learning engages learners in uncovering the relationships between terms, concepts and ideas within a topic or between topics. Deep learners are able to make connections and think meta-cognitively – that is, they think about their thinking, discuss ideas, take action and evaluate evidence as a natural part of science learning.
3. The ultimate goal in science teaching and learning is the ability to transfer learning to different contexts or problems, both inside and outside the classroom. This is what paves the way for innovation. For transfer learning to happen, the topic must be relevant to students and students must be engaged.

During the course of this unit, students will be cycling between these three types of learning.

Science Notebooks (California Academy of Sciences)

Keeping a notebook can help your students think and act like scientists. The link above is full of strategies and examples of how to use science notebooks in your classroom.

In *Ghost Particles,* students will be using a notebook provided in the Print Master, with a sample at the back of the binder. The notebook is a mix of guided learning pages and plenty of empty space for students to put down their own ideas, thoughts and drawings. The inside cover has guidelines for students on using the notebook.

The notebook scaffolds student thinking and learning at different stages of the lesson, from developing questions, to reasoning and reflecting, to consolidation of learning. The science notebook makes it easy for the teacher to see the thinking of each student and is used throughout this unit as a tool for formative assessment.

Phenomenon (Next Generation Science Standards**)**

This unit uses an **anchoring phenomenon** to drive instruction throughout the course of the unit.

In science and engineering, natural phenomena are observable events that occur in the universe and that we can use our science knowledge to explain or predict. The goal of building knowledge in science is to develop general ideas, based on evidence, that can explain and predict phenomena.

Anchoring learning in explaining phenomena supports student agency for wanting to build science and engineering knowledge. Students are able to identify an answer to "why do I need to learn this?" before they even know what the "this" is. By centering science education on phenomena that students are motivated to explain, the focus of learning shifts from *learning about* a topic to *figuring out* why or how something happens.

The point of using phenomena to drive instruction is to help students engage in practices to develop the knowledge necessary to explain or predict phenomena. Therefore, the focus is not just on the phenomenon itself. It is the phenomenon *plus* the student-generated questions that guides the learning and teaching.

Norms for Group Discussions (from Michaels, et al, *Ready, Set, Science!)*

Whether students are talking with a partner, in a small group or a full class discussion, it is important that they respect their fellow students and develop active listening skills. We suggest the following set of student norms for discussion. These are on the flash drive as a Word document so that they can be changed to fit your classroom.

1. You have the right to contribute to an attentive, responsive audience.	1. You are obligated to speak loudly enough for others to hear.
2. You have the right to ask questions.	2. You are obligated to listen for understanding.
3. You have the right to be treated civilly.	3. You are obligated to agree or disagree (and explain why) to other people's ideas.
4. You have the right to have your ideas discussed, not you, personally.	
Student Rights	**Student Obligations**

Groupwork Norms (from Cohen, et. al, *Designing Groupwork)*

In many lessons in this unit, students conduct investigations in groups of 3 or 4. In groupwork, status issues often arise which exclude some students (see *Designing Groupwork, Chapter 3).* In order to try to counter these natural tendencies, the task cards for the investigations are designed with roles for each student (when working in groups of 3 or more). In addition, we recommend introducing a set of Groupwork Norms before the first group investigation and to hand out a copy of the norms for each student to tape or paste into their notebook (we have not printed them directly because a classroom may already have established norms so you may wish to modify what we have provided). An editable file is included on the flash drive. The norms we use are:

Designing Groupwork (Chapter 4) has these helpful tips for assigning roles during groupwork and for teacher facilitation

Groupwork Norms

- Everyone has expertise.
- Everyone has something to learn.
- You have the right to ask for and offer help as well as a duty to assist.
- Pay attention to what others need.
- No one is done until everyone is done.

Procedural Roles

- The purpose of roles is to ensure a high quality discussion and a group product that are on track and on time.
- Roles relate to ***how*** the work gets done; ***intellectual roles are inappropriate***. (Intellectual roles may be: the mathematician, the reader, the scientist). If reading and math are critical to the task, then everyone in the group should be engaged in these skills and processes.
- Procedural roles must be appropriate to the task and to the number of group members.
- ***Every*** group member must have a procedural role - all the stuff in all hands.
- The procedural role is for the student to make sure that the assigned task gets done, not necessarily that the student does it alone. (e.g. the note taker makes sure everyone has notes).

Teacher Facilitation Tips for Successful Group Roles

1. Assign roles; if you let the group choose their own roles, they will tend to give whatever they perceive as the most desirable and powerful role to the person with the highest status.
2. Make role assignments public knowledge both visually and verbally (consider procedural role name tags that refer to the student's procedural role to the group).
3. Provide a written "job description" for each role.
4. Make sure everyone knows what each role is supposed to do.
5. Provide students opportunities to learn each of the roles in low stakes environments.
6. Think carefully about assigning facilitation roles, especially as students are learning groupwork. In particular, the facilitator should be assigned thoughtfully because it is a high status role. This can raise a person's status if low status, but can also cause anxiety if the person does not have practice in this role. This role can also increase a high status student's status. Every student, over time, should be assigned the role of facilitator.
7. Hold students accountable for their procedural roles.

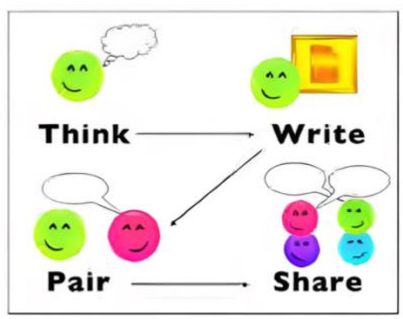
Tools for Student Discourse (see the Resources section)

Being an effective communicator involves not only talking, but also active listening. The Partnership for 21st Century Skills highlight the importance of developing communication skills in preparation for college and career readiness. These skills are not always easy to acquire. Being a good listener is tough, particularly when some members of the group are passionate, knowledgeable or opinionated.

In this unit, we use several strategies to encourage student discourse. Before the first discussion, we recommend passing out *Students Rights and Obligations for Discussion*, talking through them and having students paste them in their notebooks. It may be necessary to remind students to reread them from time to time.

Think-Pair-Share

Think-Pair-Share (T-P-S) is a learning tool that helps foster independent thinking and collaboration in classroom discussions. The teacher asks an open-ended question and students think quietly about it for a minute or two. Then every student pairs up with a partner and they discuss the question for two to five minutes. Finally, the whole class engages in a discussion where students can share all the thoughts and ideas they have gathered.

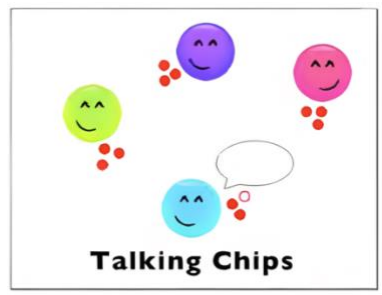


In *Ghost Particles*, TPS is used early and often. In the launch of the unit, a TPS activity is scaffolded using the Science Notebooks in order to give students structured practice in its use. By the end of the unit, they should be comfortable with the process.

Talking Sticks

There are stories of indigenous peoples from around the world using "talking sticks" to ensure equity of voice. A talking stick provides everyone in the group with a visual signal as to who has the floor, and helps everyone to share equally in the discussion. Using a talking stick in the classroom can help students learn to self-monitor their participation in group discussions, leading to more purposeful contributions and better listening.
Talking sticks work best in a situation where a free-flowing classroom discussion isn't necessary, for example, to check back on student understanding after watching a video. When utilizing talking sticks in small group discussions, make sure the discussion is not always started by the same students. Pick a random parameter (longest hair, tallest, etc.) for the person who starts, or have anyone pick it up, but then have them pass it left or right to start. Then the talking stick will move around the circle in the direction designated by the facilitator.

Talking Chips



Talking chips allow for a more free-flowing discussion but still encourages participation by everyone in the group. Each student gets 1-3 chips. Each time they want to express a thought they put one of their chips in the center. When their chips are gone, they are not allowed to talk until everyone in the group has used all their chips.
Then if time has not been called, everyone can take their chips back and start again. A talking chip can be any small manipulative.

Tools for Student Reflection on Content Learned (California Academy of Sciences, Science Notebook Corner)

Sentence Frames (I noticed/I learned/ I wonder/ I think) is one of several reflection tools that have been developed to help students realize just how much they have learned after a science lesson and to give them an opportunity to revise their thinking. Using four phrases as prompts, students can select which ones and how many they would like to use without limitations. They may have a lot of 'wonderings' and no 'learns' and you can ensure them that is fine.

3-2-1

There are multiple versions of the **3,2,1** prompt. They include:

- 3 things I learned, 2 interesting facts, 1 question I still have
- 3 things I observed, 2 things I wonder, 1 general rule
- 3 things I noticed, 2 questions I have, 1 analogy

In *Ghost Particles*, these two prompts are used at various transition points during the unit to encourage reflection and consolidate learning.

Resources

Books

1. J. Almarode, D. Fisher, N. Frey and J. Hattie, *Visible Learning for Science: What Works Best to Optimize Student Learning;* Corwin Publishing (2018).

2. S. Michaels, A. W. Shouse, and H.A. Schweingruber, *Ready, Set, Science! – Putting Research to Work in K-12 Classrooms;* National Academies Press (2008).

3. E. Cohen and R. Lotan, *Designing Groupwork: Strategies for the Heterogeneous Classroom;* Teachers College Press, Columbia University (2014).

Online Resources

4. The California Academy of Sciences, *Science Notebook Corner.*

5. Next Generation Science Standards, Resources on Phenomena**.**

6. Western Governors University, Hey Teach! Resources: Think-Pair-Share

7. E.L. Achieve**,** Structured Talk Resources ***Note****: This set of resources targets English Language Users, but the strategies included (Think-Pair-Share, Talking Sticks and Talking Chips, plus others) are excellent for any classroom.*

Ghost Particles

Materials List

- **Teacher-Provided**

Lesson	Materials Needed
1	***Launch*** *– Students will be working with page 5 of their Science Notebook* For each student ➢ Science Notebook • Colored Pencils (share with another student) ***Exploration*** *– Students will be working with page 6 of their Science Notebook* For the classroom • Clear 20oz cup, partially filled with water • Storage container w/ salt • Clear covered vial w/ salt For each pair of students • Lesson 1 Task Card • 180cc beaker or marked clear cup • 5mL scoop • Plastic spoon or stir stick ➢ Water ***Summary*** *– Students will be working with page 7-8 of their Science Notebook*
2	***Exploration*** *– Students will be working with page 9 of their Science Notebook* For each pair of students ➢ Science Notebook ➢ Scissors • 'Size of Things' measuring o Yellow Decimeter Strips (10) o Yellow Centimeter Squares (10) o Paper cm Square (several) o 15cm ruler o .1mm wire in sample bag • Handheld microscope • One 'scale plate' (black plate w/ two scales on it) ***Summary/Assessment*** *– Students will finish page 9 of Science Notebook.* *Page 10 is for additional reflections they have about lessons 1&2* For each student • Lesson 1 exit card • Index card

3	***Launch – Students will be working on page 11 of their notebook*** For each student ➢ Science Notebook • Exit Card from Lesson 2 For the classroom • Laminated number line • Masking or painter's tape ***Exploration A – Students will be working with page 12 of their Science Notebook*** For the classroom • 1 set small measuring spoons • 1 container kosher salt For each student ➢ Science Notebook • Lesson 3 Task Card (share with another student) - Investigation A • One scale plate • Materials Bag containing o One toothpick o One hand lens o One spoon ***Summary A – Students will work with page 13 of their notebook*** ***Exploration B – Students will be working with page 14 of their notebook*** For the classroom • 1 set small measuring spoons • 1 container kosher salt • Digital scales (4, set up around the classroom) For each student ➢ Copy of Groupwork Norms (Print Master) For each group of students (3) ➢ Science Notebook • Lesson 3 Task Card - Investigation B • Materials Bag from Investigation A • One weigh boat ***Summary B – Students will be working with page 15 of their notebook*** For each group of students (3) • Science Seminar Task Card For each student ➢ Talking chip

4	***Launch –*** *Students will work with page 16 of their notebook* For each group of students (3) ➢ Talking Chip ***Exploration*** *– Students will work with page 17 of their notebook* For each group of students (3) • Lesson 4 Task Card • Any materials used from lessons 1-3 • 100ml graduated cylinder ➢ Water ***Summary –*** *Students will work with pages 18-20 of their notebook* For the classroom • (Optional) Set of 3 labeled vials (sand/gravel) For each pair of students • Set of dot sheets • Hand lens
5	***Launch –*** *Students will work on pages 21-23 of their notebook* ***Exploration*** *– Students will work on pages 24-31 in their notebooks* For each group (3) • Talking stick • Lesson 5 Task Card • Small/Large balloons • Balloon Pump • Wire Hanger • 12” & 16” Rulers • Heavy String • Kite String • Rubber Bands • Paperclips ➢ Scissors • Painters Tape • Scotch Tape ***Summary-*** *Students will work with pages 28-30*

6	***Launch** - Students will be work on pages 34-35 notebook* ***Exploration –** Students will work on page 36 of their notebook* For the classroom • Welding rod • Extra supplies (aluminum foil, balloon, paper clips) for multiple classes For each group of students (2) • Electroscope Task Card • Clear plastic cup with hole in bottom • 15-cm Ruler • Electroscope kit o Large Paper Clip o Aluminum Foil o Balloon o Wool Cloth o Comb ➢ Scissors
7	***Launch -**Students will work on page 38 of their notebook* For group of students (6/7) • Talking stick ***Exploration –** Students will work on pages 39-40 of their notebook* For the classroom ➢ Meter Stick • 10-meter rope • Laminated atom, nucleus, electron, neutrino cards • Blue painters tape • Salt (1 grain) • Small sticky notes For each pair of students • Modelling an Atom Task Card • Marble • 30-cm ruler • Map of Levi Stadium (49ers) • Two sticky notes (Optional Activity) for small group (3/4) • Ball of string ➢ Meter stick • Grain of salt ***Summary** – Students will work on pages 37-38 of their notebook as they learn about neutrinos and reflect on what they have learned.* • All About Neutrinos Poster • Colored Pencils

Ghost Particles

<table>
<tr><th>Lesson 1</th><th>A Salty Topic</th></tr>
<tr><td>Three Dimensional Teaching and Learning</td><td>
Logistics. This lesson is designed to take one or more class periods, depending on the extent of students’ prior knowledge on the properties of matter, and whether they are familiar with science note booking. The structure and flow of the lesson is given at the beginning of the Background Material section.
Synopsis. Students review the properties of matter, then are introduced to an anchoring phenomenon for this unit with which they are most likely very familiar – salt ‘dissolving’ into water. On the ‘macroscopic’ (bulk) level, matter has observable properties. But what physically happens to the salt? Students will ask questions about the nature of matter and figure out answers over the course of the unit.
Anchoring Phenomenon for unit: What is happening at the macroscopic (bulk) level and microscopic (particle) level when salt mixes with water and seems to disappear?
Building toward
5-PS1-3. Make observations and measurements to identify materials based on their properties.
Disciplinary Core Ideas
✓ PS1.A Structure and Properties of Matter
Science and Engineering Practices
✓ Asking questions
✓ Developing and using models
Crosscutting Concepts
✓ Structure and Function
Connecting to ELA and social studies
✓ The optional reading ‘Notable Notebooks’ gives students an opportunity to practice reading and comprehension.
✓ Throughout the unit, the use of Science Notebooks presents students opportunities to practice and improve their writing and reasoning skills.
Driving questions
✓ In science, what is meant by the <u>properties</u> of objects?
✓ When we mix salt with water, how do the properties change?
✓ What is happening when the salt is mixed with water? Can I draw a model for the combined salt+water system? What questions do I still have?
Learning Goals for Lesson 1
✓ Students will develop and understanding of what is meant in science by properties of matter and how the properties can change when substances are mixed to make a new system.
✓ Students will ask questions and begin to develop a mental model of what is happening when a solid (salt) is mixed with a liquid (water).
</td></tr>
</table>

Ghost Particles

Background Information	**<u>Structure of Lesson</u>** (PRE-LAUNCH) Students are introduced to their Science Notebook and how to use it. (LAUNCH) Students review what is meant by properties of matter by exploring a common object. *DRIVING QUESTION: In science, what is meant by the properties of an object?* (EXPLORATION) Students observe two substances – salt and water – before and after they are mixed. This is the unit phenomenon. *DRIVING QUESTION: When we mix salt and water, how do the properties change?* (SUMMARY) Students develop ideas of what might be happening in the salt + water system, and generate questions for further sensemaking. *DRIVING QUESTIONS: What is happening when the salt is mixed with the water? Can I draw a model for the combined salt+water system? What questions do I still have?* **<u>Science Content specific to Lesson 1</u>** The **macroscopic** world of objects is what students experience every day. In earlier grades, students explore the **physical properties** of objects in the form of solids or liquids. Physical properties can be **measurable** with tools or **observable** with the senses. **TEACHER NOTE:** Definitions of science terminology in bold are included later in this lesson. There are student glossary pages in the back of the notebooks. We suggest students add definitions to those pages in their own words. **<u>Math Content specific to Lesson 1</u>** **<u>Educational Strategies introduced in Lesson 1</u>** (see the background material at the beginning of the unit for more information) ✓ Science Notebooking ✓ Phenomena ✓ Norms for Discussion ✓ Student Discourse: Think-Pair-Share

Ghost Particles

	<u>Resources used in Lesson 1</u> ✓ The book, *Notable Notebooks: Scientists and their Writings,* published by NSTA Press for Grades 3-5, is an introduction to the importance of science notebooks, and is included as a pdf on the unit flash drive; ✓ The video, *Science Notebooking – How I Use my Science Notebook* from the California Academy of Sciences Science Notebook Corner. More at https://www.calacademy.org/educators/science-notebook-corner
Materials	***Launch*** *– Students will be working with page 5 of their Science Notebook* For each student • Science Notebook • Colored Pencils (share with another student) ***Exploration****- Students will be working with page 6 of their Science Notebook* For the classroom • Clear 20oz cup, partially filled with water • Storage container w/ salt • Clear covered vial w/ Salt For each pair of students • Lesson 1 Task Card • 180cc beaker or marked clear cup • 5mL scoop • Plastic spoon or stir stick • Water ***Summary*** *– Students will be working with page 7-8 of their Science Notebook* For each student • Colored Pencils (share with another student)
Prior Knowledge	In earlier grades, students should have explored the properties of matter using their senses. Matter is something they can see or touch. They learn that matter can be solid or liquid. This prior knowledge may need to be reviewed. Building an understanding that matter might be too small to see is an abstract and difficult concept that we will be introducing over the course of this unit. This lesson starts with describing common physical properties of common objects. The term matter is intentionally NOT introduced until after gases are explored in Lesson 5; at that point, an optional video is available that introduces other properties of matter.

Ghost Particles

Launch	
Engagement / Assessing Prior Knowledge	1. *PREQUEL (optional)* As a class, read the poetry book *Notable Notebooks: Scientists and their Notebooks,* and discuss as a class why keeping a notebook is very important for scientists. 2. (Slide 3) Introduce the new unit of study by reminding students that they are scientists too, whenever they are questioning and investigating the world. Pass out a Ghost Particles Science Notebook to each student and giving them a chance to look through it. Then show the video *Science Notebooking – How I Use My Science Notebook* from the California Academy of Sciences (linked from the lesson PowerPoint file and in the Video folder on the unit flash drive). After the video, let students know that tips on using their notebook are on the inside cover. *DRIVING QUESTION: In science, what is meant by the properties of an object?* 3. What do we mean by the **properties** of an object? Give students a couple of minutes to write down a definition in their own words in the Science Journal *(Page 5).* Then hold up a common object (for example, a book) and ask students to first draw a picture, then to write down – without naming the object - four properties of it(for example, red, square, large, heavy) in their science notebooks (*Page 5*). Go around the class and have each student state one property they thought of, writing the answers on the board without comment, until students run out of answers. ***TEACHER TIP****: If students object to not using the name of an object in the list of its properties, you may need to have a class discussion that there can be many names, in many languages, for the same physical object.* 4. Are all the words listed on the board **physical** properties? Can they be observed using the five senses or measured using tools? If there is something in the list that is not a physical property, put a star next to it, then ask students to think for a minute about what is different about those words than the others. Then they should turn to the person next to them and share their thinking. One person will share first, then listen while the second person shares. Does their reasoning agree? Are they confident that they understand what a physical property of an object is?

	5. What listed properties can be measured? These are **measurable properties** (examples are words denoting size or volume, weight, density). Circle properties students think are measurable and have them pick two or more to write down in their notebook (*Page 5*). Other properties might be **observable properties** that are described using the five senses, for instance, color, taste, smell, or state (solid or liquid). Circle those in a different color and have students pick two or more to write down in their notebooks. ***TEACHER NOTE:*** *There will be an opportunity at the end of Lesson 5 to watch a video that introduces other physical properties that students may not think about here, such as magnetism, solubility, density.*
Exploration	
Develop and Use Models: Part 1 – Examining Scales	*DRIVING QUESTION: When we mix salt and water, how do the properties change?* 1. Hold up two samples, one solid (salt) in a vial and one liquid (water) in a cup. Walk around the classroom so everyone can observe them closely. Have students write three properties of each substance in the table in their notebook (*Page 6)*. 2. Organize students into pairs, and pass out a Lesson 1 Task Card to each pair of students. Students will gather their supplies (a cup, a 5 milliliter scoop of salt, a stick or spoon to stir with and water) and follow the instructions on the task card. Students will trade roles and redo the experiment so that both students get an opportunity to observe. Then students will write down three things they noticed when the two substances were mixed, and three properties of the combined salt + water system (*Page 6)*.
Summary	
Consolidation of Learning	*DRIVING QUESTIONS: What is happening when the salt is mixed with the water? Can I draw a model for the combined salt+water system? What questions do I still have?* 1. Pass out a copy of the Norms for Discussion (Print Master) and give students a minute to tape or paste into their Science Notebooks (*Page 4)* and read silently. Let students know that these Norms are in effect anytime they are talking to a partner, a small group or as a full class. Go over each bullet and ask students if they understand and agree. ***TEACHER TIP****: Your classroom may already have discussion norms that students understand and use; in that case you can skip Step 1 and just remind students that they are in effect. The Print Master version is in Word so that it can be changed as you wish before printing.*

	***TEACHER TIP**: The next three steps constitute the first time students participate fully in a Think-Pair-Share activity in this unit, so it is scaffolded using their Science Notebooks.* 2. (THINK) Ask students to think about what happened when the two substances were mixed and write down some ideas in their notebook (*Page 7)*. ***TEACHER TIP**: Do not introduce the term 'dissolve' during this lesson. Students might be familiar with the term and try to use it in their explanation. If they do, let them know that you wonder what they mean by that and could they explain further.* 3. (PAIR) Once students have finished, have them turn to their nearest neighbor and compare ideas. They should put check marks next to the ideas that they both had and write down ideas that their partner thought of that they didn't (*Page 7)*. Each pair will come to consensus on one or two ideas to present to the rest of the class and circle them. 4. (SHARE) Once students are ready, have each group report out one idea and write it on the board or on a large poster sheet (to save for subsequent lessons). 5. Give each student time to write new ideas they liked in their notebook, and to draw a picture of what the combined water/salt mixture looks like (*Page -7-8)*. 6. Each student should then write down what questions they still have about what happened when the two substances were mixed (*Page 8)*. ***TEACHER TIP:** The questions students derive here are wonderments that will be returned to over the course of the unit as students begin to develop a mental model of the particle nature of matter. If there is not time to discuss them in class, you may need to have students turn in their notebooks at the end of the day so that you can transfer these questions to a class list and post for the remainder of the unit.*

Ghost Particles

New Terminology and Concepts	**Physical property of an object or substance –** The physical properties of an object or substance are observable or measurable characteristics that make it unique. **Measurable physical properties** are properties which are measured with a tool. Examples of measurable physical properties are weight (mass), length, volume, density, etc. **Observable physical properties** are properties in which you use your five senses to get information about an object. If you can describe the matter based on what it looks, feels, smells or tastes like, you are describing the physical properties. Some examples of observable physical properties are color, odor, taste, state (solid, liquid), etc.
Connection to Big Ideas (DCI)	This lesson gives students an opportunity to review what they have learned in earlier grades about properties of matter, and to question the anchoring phenomenon for the unit.
Follow Up/Practice	(OPTIONAL) Students can use Page 8 of their Science Notebook to write down any new questions, wonderments or ideas that they have about Lesson 1.
Assessment	The completed pages 5-8 of the Science Notebook constitute the formative assessment for this introductory lesson.
Optional Extension	Prequel: Read the book on Science Notebooks (on unit flash drive) before starting the unit.

Ghost Particles

Lesson 2	The Size of Things
Three Dimensional Teaching and Learning	**Logistics.** *This lesson is designed to take one class period. The structure and flow of the lesson is given at the beginning of the Background Material section.* **Synopsis.** *Students are introduced, or reintroduced, to the metric system, then apply their math skills as they explore sizes of things in the classroom and down to the limits of their vision. They use handheld microscopes to take the next step smaller. How small an object can they see with the tools they have? What tools could take them further?* **Building toward** **5-PS1-1.** Develop a model to describe that matter is made of particles too small to be seen. **5-PS1-3.** Make observations and measurements to identify materials based on their properties. **Disciplinary Core Ideas** ✓ PS1.A Structure and Properties of Matter **Science and Engineering Practices** ✓ Using mathematics and computational thinking **Crosscutting Concepts** ✓ Scale, Proportion and Quantity ✓ Patterns **Associated SD Mathematics Standards** **5.MD.A.** Convert like measurement units within a given measurement system. **Connecting to ELA and social studies** ✓ Throughout the unit, the use of Science Notebooks presents students opportunities to practice and improve their writing and reasoning skills. **Driving questions** ✓ What is the metric system? ✓ How can we use the property of size to characterize objects we observe? What patterns do we observe? ✓ How can we use technology to see objects too small to observe with our eyes? ✓ What are powers of 10 and how do they help us describe the size of objects? **Learning Goals for Lesson 2** ✓ Students will examine the size and other properties of objects from 1 meter to 0.01 millimeters and identify patterns.

Background Information	**Structure of Lesson** (LAUNCH) Students are introduced to the metric system. *DRIVING QUESTION: What is the metric system?* (EXPLORATION) Students explore the property of size in the range of one meter to 0.01 meters to begin sensemaking of the idea that some things are too small to see. They utilize mathematics and detect patterns that will continue as they explore even smaller sizes in subsequent lessons. *DRIVING QUESTION: How can we use the property of size to characterize objects we observe? What patterns do we observe?* (SUMMARY/ASSESSMENT) Students explore technology for 'seeing' the next power of ten below the limits of our eyes. They consolidate their learning with the formative assessment for the lesson. *DRIVING QUESTION: How can we use technology to observe the properties of objects too small to see?* **Science Content specific to Lesson 2** (terminology in bold is defined in the vocabulary section) The size of an object is one measurable physical property. Scientists use the **metric system** as a standard unit of measurement. Using the metric system, students will review the units of size for macroscopic objects in our world (**meter**, **decimeter**, **centimeter** and **millimeter**) and then use and/or learn about tools (**magnifying glass (hand lens)** and **microscope**) to start exploring objects at the **micrometer** scale. They review the mathematical concept of **powers of 10**. (Scientists refer to this as orders of magnitude.) **TEACHER NOTE:** Definitions of science terminology in bold are included later in this lesson. There are student glossary pages in the back of the notebooks. We suggest students add definitions to those pages in their own words. **Math Content specific to Lesson 1** In Lesson 1, students will begin their investigation of matter by examining the size of things they can see and practice estimating size, measuring, and scaling objects by powers of 10. They will use the metric scale and the following prefixes as they move to smaller and smaller objects: ➢ 1 decimeter = 0.1 (1/10) meter; 10 decimeters = 1 meter ➢ 1 centimeter = 0.01 (1/100) meter; 100 centimeters = 1 meter ➢ 1 millimeter = 0.001 (1/1,000) meter; 1000 millimeters = 1 meter

There are no prefixes defined for 0.1 mm (1/10,000) meter or 0.01 mm (1/100,000) meters. Maybe the class would like to come up with their own names for those scales. For the 0.01 mm microscope images in the PowerPoint, the images are labeled with a new unit of size, 10 micrometers, with the symbol µm. One micrometer is 1/1000 of a millimeter, or 1-millionth of a meter. We will talk more about this scale in later lessons. *(The symbol µis lower case version of the Greek letter Mu, their version of the letter M (the capital Mu is M, just like our alphabet.))*

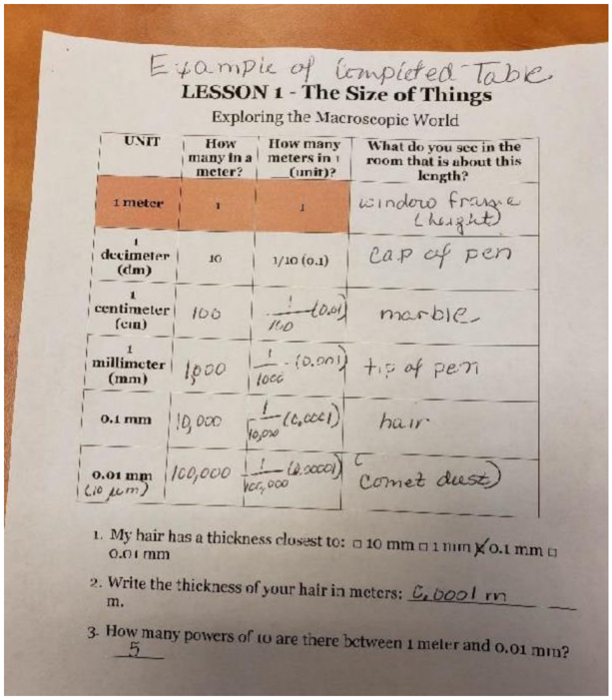
Educational Strategies introduced in Lesson 2 (see the background material at the beginning of the unit for more information)

- ✓ Student Reflection: Sentence Frames

Resources used in Lesson 1

- ✓ References for images in Slide 5
    - Comet dust Cecile Engrand, et al., *Variations in cometary dust composition from Giotto to Rosetta, clues to their formation mechanisms* Monthly Notices of the Royal Astronomical Society (MNRAS) **462**, S323 (2016);
    - Dividing Newt Cells: Conley L. Reider and Alexey Khodjakov, *Mitosis Through the Microscope: Advances in Seeing Inside Live Dividing Cells,* Science Magazine **300,** 91 (2003);
    - Spirulina algae https://www.freshspirulina.com.au/spirulina/spirulina-under-the- microscope/ (microscope images of spirulina algae at different resolutions);
- ✓ The graphic in Slide 6 (Relative Size and Detection Devices) comes from a cell biology and microscopy website at Florida State University (https://micro.magnet.fsu.edu/cells/index.html). This website contains much additional information about the size of biological systems.

Example of completed table (Page 9 of Science Notebook)



Example of Completed Table

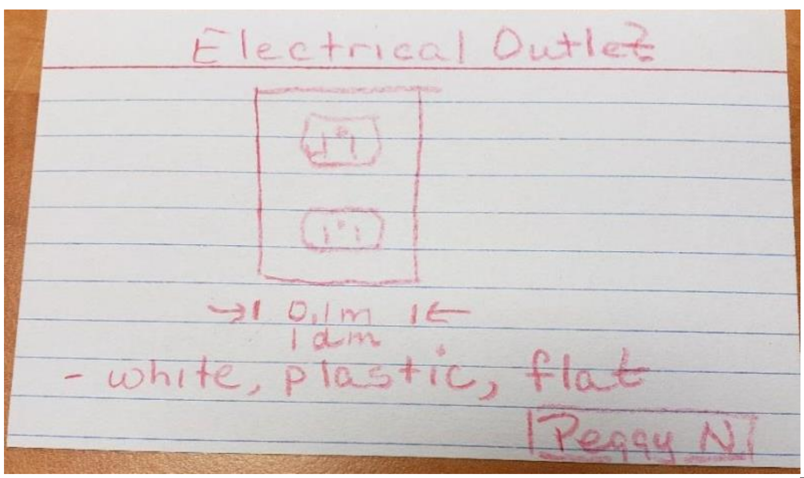
LESSON 1 - The Size of Things

Exploring the Macroscopic World

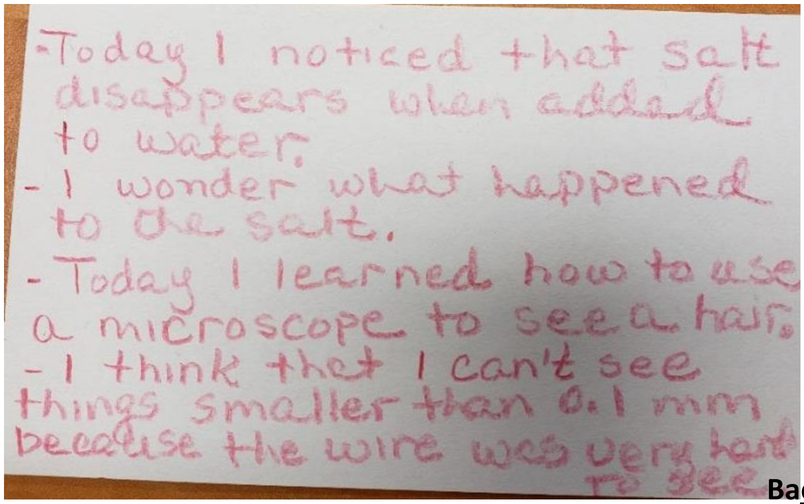
UNIT	How many in a meter?	How many meters in 1 (unit)?	What do you see in the room that is about this length?
1 meter	1	1	window frame (height)
1 decimeter (dm)	10	1/10 (0.1)	cap of pen
1 centimeter (cm)	100	1/100 (0.01)	marble
1 millimeter (mm)	1000	1/1000 (0.001)	tip of pen
0.1 mm	10,000	1/10,000 (0.0001)	hair
0.01 mm (10 µm)	100,000	1/100,000 (0.00001)	(comet dust)

1. My hair has a thickness closest to: ☐ 10 mm ☐ 1 mm ☒ 0.1 mm ☐ 0.01 mm
2. Write the thickness of your hair in meters: 0.0001 m m.
3. How many powers of 10 are there between 1 meter and 0.01 mm? 5

Example of completed index card (assessment)



Front of card

	 **Back of card**
Materials	***Exploration*** *– Students will be working with page 9 of their Science Notebook* For each pair of students • Science Notebook • Scissors • 'Size of Things' measuring ○ Yellow Decimeter Strips (10) ○ Yellow Centimeter Squares (10) ○ Paper cm Square (several) ○ 15cm ruler ○ .1mm wire in sample bag • Handheld microscope • One 'scale plate' (black plate w/ two scales on it) ***Summary/Assessment*** *– Students will finish page 9 of Science Notebook. Page 10 is for additional reflections they have about lessons 1&2* For each student • Lesson 1 Exit card • Index card • Colored pencils (shared)
Prior Knowledge	In Lesson 1, students reviewed the concept of properties and that properties can be measurable or observable.
Launch	
Engagement: Scale, Proportion & Quantity	*DRIVING QUESTION: What is the metric system?* (Slide 5) If students have not yet been introduced to the metric system in science or math class, or if it needs to be reviewed, show the video *How people (and squids) measure things* to introduce the topic (also linked from Slide 5). Then review the table on the slide which shows the metric units for length (meter), volume (liter) and weight (gram) that will be used in this unit.

Ghost Particles

Exploration	
Develop and Use Models: Part 1 – Examining Scales	*DRIVING QUESTIONS: How can we use the property of size to characterize objects we observe? What patterns do we observe? Can we use technology to see objects too small to observe with our eyes?* Students should work in pairs for the following activities: 1. Hold up a **meter** stick. Ask students to stand up and hold out their arms so their hands are about 1 meter apart, taking care not to hit their neighbor. Staying at their desks, they should look around the room with their partner and find something that they agree is approximately 1 meter (length or width). Draw or write it in the top row (1 meter) of the table in their notebook *(Page 9)*. 2. Pass out the *Size of Things* measuring bags (1 per pair of students). Then point out on the meter stick the 1/10th of a meter (1 **decimeter**) mark. Have students hold their two index fingers approximately that distance apart. Can they find something in their bag that is the same length? *There are 10 1- decimeter strips in each bag.* Have students line up all 10 on their desks, table or floor (depending on how room is configured). Are the 10 strips as long as one meter stick? The teacher can walk around the room with the meter stick so students can check. Have students look at the one decimeter row of the table in their notebook (*Page 9)*. The row is partially completed. There are 10 decimeters in a meter. That means a decimeter is 1/10th of a meter. They could write it as 1/10, but they can also write it as 0.1 meter. Have them look around the room with their partner and find something they think is approximately 1 decimeter in length or width, then draw or write it in their notebook. How many of that item would they need to make something one meter long (or wide)? 3. Next, students should remove the 10 yellow **centimeter** squares from their bag, line them up and compare the length to the decimeter strip. Discuss as a class. How many of the 1-centimeter squares equal a decimeter? (*10)* How many groups would have to get together to have enough centimeter squares to be as long as 1 meter? (10) How many squares would be in a meter? (*100)* What part of a meter is 1 centimeter? *1/100 (0.01)* Have them fill in the next row on the table in their notebook, then look around the room with their partner and pick out something about 1 centimeter and write or draw it in their notebook.

4. Can we go another factor of 10 smaller? Have each pair take the short ruler from their bag and hold the metric side next to a 1 cm yellow square. The smallest markings on the ruler are **millimeters**. Counting on their ruler, how many millimeters are in a centimeter? (10) Have students fill out the 1 millimeter row in their table. There are 1000 millimeters in a meter. A millimeter (mm) is 1/10th of a centimeter (*1/1000 or 0.001 meters*). Each pair will look for something in the room they think is about 1 mm and write it in their notebook.

5. The next power of 10 below 1 millimeter, 0.1 mm, is in the next to the last row of Table 1. It does not have a special name. Students should see a pattern now and be able to fill in the row without having to measure things. ***OPTIONAL****: You could let the class suggest a name for this unit of measurement that they can use for the rest of the unit.*

6. Each bag has several paper centimeter pieces. Students can see if they can evenly cut one into 10 equal pieces of 1 mm each. *Please do not cut the plastic pieces*. Do they think they could cut one of the 1 mm pieces into 10 equal pieces of 0.1 mm with their scissors?

7. Students will have a piece of wire in their bag that is 0.1 mm diameter. The wire is inside a small sample bag, so it won't get lost; do not remove it from the bag! Do they see anything at their desks or around the room that is as small as this? Add it to the table. *Students might come up with a human hair. Human hairs vary between a little more than 0.01 to a little more than 0.1 millimeters.*

8. Suggest that each student pull one hair (or see if there are any on their clothing) and estimate whether it is smaller, larger or about the same as their wire sample. Is it much smaller?

9. What tools could be used to look at an object this small? Students might come up with a **magnifying glass** (hand lens) and/or a **microscope**. Pass out the hand microscopes and a black 'scale plate' (one per pair of students) and let students take turns looking at their hair and the wire through this.

TEACHER TIP*: Suggest that students first focus the microscope on one of the lines on the plate before looking at a hair or the wire. They need to have the microscope very close to the object they are looking at.*

	10. How could they use the plate to measure the size of something? Point out the two scales on each plate (1 millimeter and 0.1 millimeter). Could these scales be used to estimate the size of their hair strand? Have students lay their hair on each scale and determine which one is closest to the diameter of the hair. Can they look at the hair and scale together with the microscope? After they decide the diameter of a hair to the nearest power of 10, they can answer the first two questions below the table in their notebook (*Page 9)*. 11. Ask for a show of hands as to how many students had hairs that were closer to 1 millimeter and how many closer to 0.1 millimeter. Did any students find hairs that were smaller than 0.1 millimeter? 12. Poll the class about whether they think they would be able to see an object that was 0.01 millimeters, or 1/10th the size of the wire, with their eyes? With the hand microscope? Has anyone in the class used a microscope to look at objects that are too small to see with the naked eye? 13. (Slide 6) Have students fill out the first two columns in final row of the table, then show the PowerPoint slide with three microscope images that are each approximately 0.01 mm. The left photo is microscopic dust from a very old comet, found in the ice of the Antarctic. The middle photo is cells of a newt dividing. The right photo are cells from spirulina algae. Give students time to write a description or to draw a picture of one of these to finish up the last row of their notebook. ***TEACHER TIP****: The images are labeled with a new unit of size, 10 micrometers, with the symbol µm. One micrometer is 1/1000 of a millimeter, or 1-millionth of a meter. We will talk more about this scale in later lessons. More information about the symbol µis in the background section.*
Summary	
Consolidation of Learning	*DRIVING QUESTIONS: What are <u>powers of 10</u> and how do they help us describe the size of objects?* 1. (Slide 7) How many **powers of 10** have we spanned from 1 meter to 0.01 millimeter? To answer this question, show the PowerPoint slide with the powers of 1o studied today, and have students either look at their own table or the slide and count out loud while they move from 1 row to the next from 0.01 millimeter to 1 meter. *5 powers of 10.* Going up a power of 10 is the same as multiplying by 10. Going down a power of 10 is the same as dividing by 10. Answer Question #3 in their notebook (*Page 9)*. 2. To finish up this lesson, give each student an Exit Card (front and back), an index card to turn in, and a set of colored pencils (share with a partner). REMIND THEM NOT TO WRITE ON THE EXIT CARD. The task card will present them an opportunity to show and reflect on some of their learning from the lesson. The reflection will be done using Sentence Frame tools.

	Before they start, make sure everyone understands that their four reflections can use any of the four sentence starters; they do not have to use all four. This is the exit card and assessment for this lesson. 3. (OPTIONAL) Using Page 10 of their Science Notebook, in class or as homework, have students reflect in words or drawings about how what they learned about in Lesson 2 (*The Size of Things)* might help answer some of the questions they had at the end of Lesson 1 about what happened when salt was mixed into water.
New Terminology and Concepts	**Metric System –**a system of weights and measures in which the meter is the unit of length, the liter is the unit of volume, and the gram is the unit of weight. **Meter -** the basic unit of distance in the metric system **Decimeter –**a metric unit of length, equal to one tenth of a meter **Centimeter -** a metric unit of length, equal to one hundredth of a meter **Millimeter-** a metric unit of length, equal to one thousandth of a meter **Micrometer-** a metric unit of length, equal to one millionth of a meter **Magnifying glass (hand lens) –**a lens that produces an enlarged image, typically set in a frame with a handle and used to examine small or finely detailed things such as fingerprints, stamps, and fine print. **Microscope –**an instrument used to see objects that are too small to be seen by the naked eye. An optical microscope can see objects on the micrometer scale. **Powers of 10 -** In mathematics, a power of 10 is ten multiplied or divided by itself a certain number of times.
Connection to Big Ideas (DCI)	Students are introduced (or review) the metric system as the established scientific measurement system for the property of size. They begin to 'scale' to increasingly smaller sizes (CCC: *Scale, Proportion and Quantity)* and review the mathematical concept of powers of 10 to describe small sizes.

Ghost Particles

Follow Up/Practice	Ask students to use Page 10 of their notebook to reflect on what they learned about size in this lesson and how that might apply to the salt+water phenomenon from Lesson 1.
Assessment	The exit cards are the assessment for this lesson. An example of a completed card is given in the Background Information section.
Optional Extension	1. Have each group report out on what objects students noted that were about the size of a decimeter, centimeter and millimeter. Write them in three columns on the whiteboard. After you have made the list, have each pair, using the ruler in their bags, measure the objects they contributed to each column. Students will write the actual size on the board next to their objects. 2. Facilitate a class discussion about how close students were in estimating the size of things in their classroom from their desk. Were they fooled about some objects? What could cause them to under- or over-estimate? Was it easier to estimate a millimeter, centimeter, decimeter, or meter? Why do they think that is the case?

Ghost Particles

<table>
<tr><th>Lesson 3</th><th>Now You See It…</th></tr>
<tr><td>Three Dimensional Teaching and Learning</td><td>

Logistics. *This lesson could take two class periods, due to the fact that there are two investigations and a science seminar. The structure and flow of the lesson is given at the beginning of the Background Material section.*

Synopsis. *Students continue their exploration of scale, proportion and quantity by examining the properties of salt grains at multiple sizes.*
They plan and carry out an investigation to determine whether the weight of a quantity of salt changes when the grains are different sizes.

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

5-PS1-2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

5-PS1-3. Make observations and measurements to identify materials based on their properties.

Disciplinary Core Ideas

- ✓ PS1.A Structure and Properties of Matter
- ✓ PS1.B Chemical Reactions

Science and Engineering Practices

- ✓ Developing and using models
- ✓ Planning and carrying out an investigation

Crosscutting Concepts

- ✓ Scale, Proportion and Quantity
- ✓ Cause and Effect

Associated SD Mathematics Standards

5.5. MD.B. Represent and interpret data.

Connecting to ELA and social studies

- ✓ Throughout the unit, the use of Science Notebooks presents students with opportunities to practice and improve their writing and reasoning skills.

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	Driving questions ✓ What is matter? Are all the objects we examined in Lesson 2 matter? ✓ How do the properties of salt change with size? ✓ Are all the properties of salt the same when you crush it or do some of them change? ✓ Does the weight of salt change when it is crushed into smaller pieces? ✓ Is salt matter? What have we learned so far about salt that could help explain what happens when it is mixed with water? **Learning Goals for Lesson 3** ✓ Make observations and draw conclusions whether or not properties of salt stay the same or change when crushed. ✓ Plan and carry out an investigation to show that the weight of a substance is conserved even when it is too small to see and that salt retains the properties of matter even when crushed very small.
Background Information for performance expectation	**Structure of Lesson** (LAUNCH) Students pick up where they left off with their exit cards from Lesson 1. They are introduced to the classroom number line and add their exit cards to the appropriate power of 10. They are introduced to (or review) the concept of matter having measurable properties (weight and volume). *DRIVING QUESTION: What is matter? Are the objects we examined in Lesson 2 matter?* (EXPLORATION A) Students continue their exploration of the transition between macroscopic and microscopic scales by examining the properties of salt as they grind it very small. *DRIVING QUESTION: How do the properties of salt change with size?* (SUMMARY A) Students compare and contrast the observable properties of crushed and uncrushed salt. *DRIVING QUESTION: Are all the properties of salt the same when you crush it or do some of them change?* (EXPLORATION B) Students make a prediction, then carry out an investigation to determine whether or not the weight of a sample of salt changes when it is ground very small.

DRIVING QUESTION: Does the weight of salt change when it is crushed into smaller pieces?

(SUMMARY B) Students hold a science seminar to discuss the results of their investigation and come to consensus as a class. They reflect on how their studies of salt have informed the questions they had about the unit phenomenon.

DRIVING QUESTION: Is salt matter? What have we learned so far about salt that could help explain what happens when salt is mixed with water?

Science Content specific to Lesson 3 (terminology in bold is defined in the vocabulary section)

The term **matter** refers to the substance that makes up all the objects in the world around us, those things that have physical properties that can be measured or observed. In elementary textbooks, matter is defined as anything that has **mass** and takes up space (has **volume**), two of the measurable properties. In the elementary standards, students are expected to understand and measure the **weight** of an object rather than its mass. (The weight depends on the gravitational pull on an object, so on Earth the weight and mass are equivalent, but not if you went to Mars!)

Math Content specific to Lesson 3

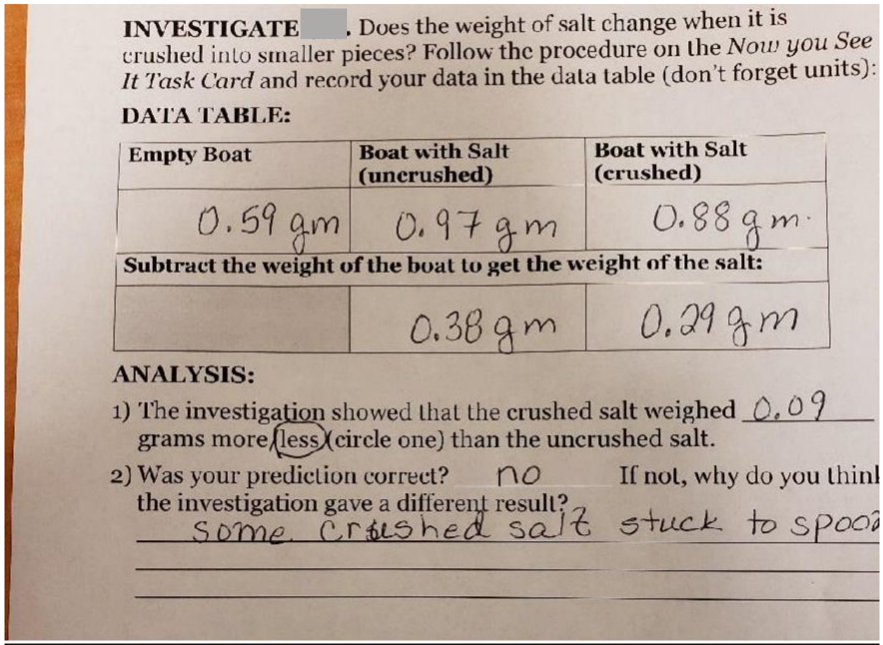
Students will analyze data, but will not be graphing until later lessons.

Educational Strategies introduced in Lesson 3 (see the background material at the beginning of the unit for more information)

- Groupwork norms
- Procedural roles
- Student Discourse: Talking Chips/Sticks
- Student Discourse: Science Seminar

Resources used in Lesson 3

1. The graphic on Slide 9 comes from the website http://www.chem4kids.com/files/matter_intro.html.

	<u>Example of completed data tables</u> **<u>Investigation B</u>**  INVESTIGATE . Does the weight of salt change when it is crushed into smaller pieces? Follow the procedure on the *Now you See It Task Card* and record your data in the data table (don't forget units): DATA TABLE: Empty Boat / Boat with Salt (uncrushed) / Boat with Salt (crushed) 0.59 gm / 0.97 gm / 0.88 gm. Subtract the weight of the boat to get the weight of the salt: / 0.38 gm / 0.29 gm ANALYSIS: 1) The investigation showed that the crushed salt weighed 0.09 grams more/less (circle one) than the uncrushed salt. 2) Was your prediction correct? no If not, why do you think the investigation gave a different result? some crushed salt stuck to spoon
Materials	(LAUNCH) *Students will be working with Page 11 of their notebook during the launch.* For the classroom • Laminated number line • Masking or painter's tape For each student • Exit Card from Lesson 2 (EXPLORATION A) *Students will be working with Page 12 of their notebook during Exploration A.* For the classroom • 1 set small measuring spoons • 1 container kosher salt

	For each student • Lesson 3 Task Card (share with another student) - *Investigation A* • One scale plate • Materials Bag containing ○ One toothpick ○ One hand lens ○ One spoon (SUMMARY A) *Students will be working with page 13 of their notebook during Summary A.* (EXPLORATION B) *Students will be working with page 14 of their notebook during Exploration B.* For the classroom • 1 set small measuring spoons (1/64 – ¼ teaspoon) • 1 container kosher salt • Digital scales (4, set up around the classroom) For each student • Copy of Groupwork Norms (Print Master) For each group of 3 students (optimal) • Lesson 3 Task Card - *Investigation B* • Materials Bag from Investigation A • One weigh boat (SUMMARY B) *Students will be working with page 15 of their notebook during Summary B.* For each group of 3 students (same as Investigation B) • Science Seminar Task Card For each student • Talking chip
Prior Knowledge	Students should be familiar with using digital scales to measure weight, but it may need to be reviewed.

Ghost Particles

<table>
<tr><th colspan="2">LAUNCH</th></tr>
<tr><td>Engagement: Observing Matter</td><td>

DRIVING QUESTIONS: What is matter? Are the objects we examined in Lesson 2 matter?

BEFORE DAY 1

- *Post Section 1 (0.01 mm – 1 meter) of the laminated number line on the wall or whiteboard at a level where students can access it (used in Launch).*

BEFORE DAY 2 (Investigation B)

- *Set up four weigh stations around the room with the digital scale.*

1. As students enter (or at beginning of lesson), hand each one their exit card from the previous lesson. They should read their four statements as a reminder of where they left off. (This will be especially helpful if they don't do science every day.)
2. (Slides 9-12) Have students turn their cards over and look at the object they drew. Was everyone able to think of three observable properties for their object? Introduce the concept of matter using PowerPoint slide 9. **Matter** is defined as an object or substance that takes up space (**volume**) and has **mass** (Slide 10-11) Solicit student ideas about how we know an item has mass or **weight**? Takes up space? Slide 12 show examples of tools that can be used to measure weight and size. Students should be familiar with most of them.
3. Working on page 11 of their Science Notebook, ask students to write down the definition of matter to refer to as we explore it in more detail. Then give them a few minutes to reflect on the object they drew on their index card. Does it fit the definition of matter? After reflecting in their notebook, they will turn to the person next to them and talk it over. Did each of their objects fit the definition of matter? Did anyone in the class draw an object that didn't fit the definition?

TEACHER TIP*: Conceivably, if any of the students chose to draw one of the microscopic objects used in Lesson 1, they might conclude that it doesn't have weight because it is too small. If any students make that argument, write it as a question on the board and tell the students the class will be gathering evidence that might help them decide the answer to that question.*

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	4. Introduce the class number line and point out the units. Remind students that in Lesson 1, students started at 1 meter, and by the end of the lesson, they were examining items that were down to 0.1 millimeter, which we could see, and 0.01 millimeter, which we couldn't see. Give students a chance to tape their card (picture facing out) on or below the classroom number line at the unit of their object, using the masking tape provided in kit. 5. Give students a few minutes to reflect and write down in their Science Notebook (*Page 11)* two things they still wonder about matter. We will be returning to these wonderments over the course of the unit.
Exploration A	
Plan and Carry out an Investigation (PART A)	*DRIVING QUESTION: How do the properties of salt change with size?* 1. Give each student a Lesson 3 Task Card, a scale plate and a materials kit containing a hand lens, a toothpick and a spoon. Then go around the room and put a 'drop' of kosher salt on each plate using the smallest of the special measuring spoons in the kit. 2. Each student will use a toothpick to carefully move 10 grains of salt to one black section of the plate. They can then use the hand lens to make observations about shapes and variations and draw them in their notebook (*Page 12)*. Are all grains the same size? Same shape? With the toothpick, students will push the grains of salt to the scale that is closest to its size. Since all grains are not perfect squares, students can pick either the length or width to measure. (Remind students not to touch the salt with their hands; a toothpick can be used to manipulate them for measuring and counting.) Record how many salt grains were in each size category (1 mm, 0.1 mm, < 0.1 mm) *Most of the salt should end up on the millimeter scale but some will be o.1 mm.* 3. Once their data is recorded, students should move all but one of the salt grains to the side of the plate, then carefully crush that one grain using the spoon. *If they press a finger or thumb into the bowl of the spoon, they will be able to push harder*. They should record the following data and observations in the second column of the Data Table (*Page 12):* a. Approximately how many grains came from crushing one grain of salt? ***NOTE:*** *This time they may want to use the smaller lens on the handle of the hand lens (x6 magnification).*

	b. Are the shapes of the crushed grains the same or different than the bigger grains? c. Picking out ten of the smaller grains, student should estimate their size (to the nearest power of 10) and fill in the second column on the table in their Science Notebook *(Page 12)*. ***TEACHER TIP****: Sorting the salt grains by size as students are doing here can be used to practice making bar graphs of the size of the salt before and after crushing. See the optional extension for this activity.* 4. Based on their data, students should answer Questions 1-4 in their Notebook (*Page 12*) on their own.
Summary A	
Analyzing and Interpreting Data	*DRIVING QUESTION: Are all the properties of salt the same when you crush it or do some of them change?* Working with a partner, students will consider the properties of salt they have observed so far in the unit. In this lesson, the properties of size and shape were examined before and after crushing. In Lesson 1, students noted other properties; suggest they flip back to Page 6 of their Science Notebook to review what they had observed earlier. Have students make a list in their notebook of all the salt properties they observed during the two lessons, plus any new ones they think about. Then with a partner, decide whether each is a property of either the uncrushed or crushed salt uniquely, or is the same whether or not it is crushed. Use the Venn diagram in the Science Notebook (*Page 13*) to classify each property in the list.
Exploration B	
Plan and Carry out an Investigation; Analyze and Interpret Data	*DRIVING QUESTION: Does the weight of salt change when it is crushed into smaller pieces?* 1. Is salt matter? To answer that, we need to determine whether it has weight, a measurable property. Give students a couple of minutes to think quietly to themselves and to predict in their Science Notebook whether the small grains of crushed salt weigh more, less or the same as the larger grains of uncrushed salt. Why are they making the prediction they make? Then poll the class. On the count of 3, have them hold up one finger for 'MORE', two fingers for 'LESS' and three fingers for 'SAME'. Count how many students thought each option and write the results on the board.

	2. Have students turn to their nearest neighbor and share why they voted the way they did. ***TEACHER TIP****: This investigation is fully scaffolded to give students practice in using the equipment and conducting a group investigation.* 3. Let's see if we can gather some evidence that will help answer this question. Students will work in groups of three for this investigation. Before proceeding, pass out the reminder of Norms for Groupwork (in Print Master) and discuss each norm to make sure everyone understands them. Give students time to paste or tape the Groupwork Norms in their Science Notebook on Page 4. 4. The task card for this investigation is on the back of the Investigation A task card. Have students read it through completely and discuss it with their team. Then assign each student one of the roles as described in the task card. ***TEACHER TIP****: Once a group has weighed the empty weigh boat, give each Materials Manager one level 'pinch' of salt using the special small measuring spoons. This is enough to be measurable but not so much that it is difficult to crush inside the weigh boat. Students may need to use their toothpick to brush salt off the back of the spoon after crushing.* 5. A data table is included on Page 14 of the Science Notebook. Once the Data Recorder has written down all the data and subtracted the weight of the weigh boat, everyone should copy the data and results into their own notebooks. Discuss the results as a group and answer the questions at the bottom of Page 14.

Summary B	
Consolidation of Learning	*DRIVING QUESTIONS: Is salt matter? What have we learned so far about salt that could help explain what happens when salt is mixed with water?* 1. The class will hold a science seminar to discuss their results. Arrange the chairs in a circle and have each experimental group bring their notebooks and sit together. Give each person one talking chip, and each experimental group a Lesson 3 Summary Task Card to refer to for discussion.

	a. First, the <u>data recorder</u> for each group will share with the other group(s) the results of their experiment. Did they determine that the weight of salt stayed the same or changed once it was crushed into smaller pieces? b. Use the talking chips to facilitate a discussion using the probing questions on the Task Card. Did all groups come to the same conclusion or different conclusions? Students may defend why they think their team's results were correct, or they might note problems that may have led to inaccurate results. c. After everyone who wishes to has a chance to give their ideas, each experiment team will consult among themselves. Do they want to defend their result or change their reasoning for why or why not the result was accurate? Have the <u>materials manager</u> for each group report out this time. Can the class come to consensus on the most likely results for the experiment? (Poll the class using one, two or three fingers.) If there is not consensus, you might discuss whether there a measurement they can repeat quickly to confirm which data is most accurate? Otherwise, accept the non-consensus and move on to the reflection/assessment activity. ***Teacher Tip**: Students should find that – if they are careful not to spill or lose any salt - the weight of the crushed and uncrushed salt is the same. If their results are very close but not exactly the same, a discussion of experimental uncertainty may be in order. They might test, for example, whether the empty weigh boat reads the same weight on all four scales.* 2. Once the science seminar has reached its conclusion, ask everyone return to their normal seats and, individually, answer the two reflection questions at the top of Page 15. When they are done, turn to a nearest neighbor and each student will read their answers to each other and discuss any differences they have. 3. Now that they have studied salt in two investigations, ask students to think about whether they have learned anything that could help inform their ideas about what happens when salt is stirred into water, and write their new ideas in their Science Notebook. ***TEACHER TIP**: It is important for students to understand that they should not go back to earlier pages of their notebooks and change the ideas they had listed, but instead make a new list. Scientists are taught to write everything in a bound experimental notebook or notebook in pen so that entries cannot be changed. They make complete notes of exactly what they did so that another scientist could repeat their work and get the same results. This is part of the scientific process.*

Ghost Particles

New Terminology and Concepts	**Matter -** the substance of which all material is made. Matter has physical properties which can be measured, such as mass, volume, density, and qualitative properties which can be experienced through the senses, such as taste, smell and color. **Volume –**the quantity of three-dimensional space occupied by a liquid, solid, or gas. Common units used to express volume include liters, cubic meters, gallons, milliliters, teaspoons, and ounces, though many other units exist. **Mass** - an intrinsic property of an object, defined as the amount of matter contained in the object; it does not depend on its volume, or position in space, for instance. **Weight –**the measure of the force of gravity on an object. Weight is different from mass. The mass of an object will never change, but the weight of an item can change based on its location. For example, a person may weigh 100 pounds on Earth, but in outer space they would be weightless. They would have the same amount of mass, though. While we are on Earth, we can use weight and mass interchangeably.
Connection to Big Ideas (DCI)	Even when matter is too small to see (ground up salt), it still has weight and takes up space.
Follow Up/Practice	
Assessment	The reflection questions and modeling on Page 15 of the Science Notebooks is the assessment for this lesson.
Optional Extension	In Exploration A, students can make a bar graph of the sizes of the grains of salts, if each student measures 10 uncrushed and crushed grains, to the nearest power of 10. An easy way to do this would be to use the class number line can be used as the x-axis, and different colored sticky notes representing the uncrushed and crushed salt.

Ghost Particles

<table>
<tr><th>Lesson 4</th><th>… Now You Don’t</th></tr>
<tr><td>Three Dimensional Teaching and Learning</td><td>
Logistics. This lesson has one investigation, planned by the students. The structure and flow of the lesson is given at the beginning of the Background Material section.
Synopsis. Students apply what they have learned about the properties of salt to the unit phenomenon, the salt/water system. They plan and carry out an investigation to measure the changes in weight and volume of the salt/water system before and after the salt is mixed with water and develop a model of the system.
Building toward
5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.
5-PS1-2. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.
5-PS1-3. Make observations and measurements to identify materials based on their properties.
Disciplinary Core Ideas
✓ PS1.A Structure and Properties of Matter
✓ PS1.B Chemical Reactions
Science and Engineering Practices
✓ Developing and using models
✓ Planning and carrying out investigation
Crosscutting Concepts
✓ Scale, Proportion and Quantity
✓ Cause and Effect
Associated SD Mathematics Standards
5.MD.B. Represent and interpret data.
Connecting to ELA and social studies
✓ Throughout the unit, the use of Science Notebooks presents students with opportunities to practice and improve their writing and reasoning skills.
Driving questions
✓ What investigations could give us new evidence about what happens when salt is added to water?
✓ If something is too small to see, is it still matter (has weight and volume)?
✓ How does the data we collected and analyzed help explain what happens when the salt is stirred into the water? Are there similarities with a simple model of dots printed on a piece of paper?
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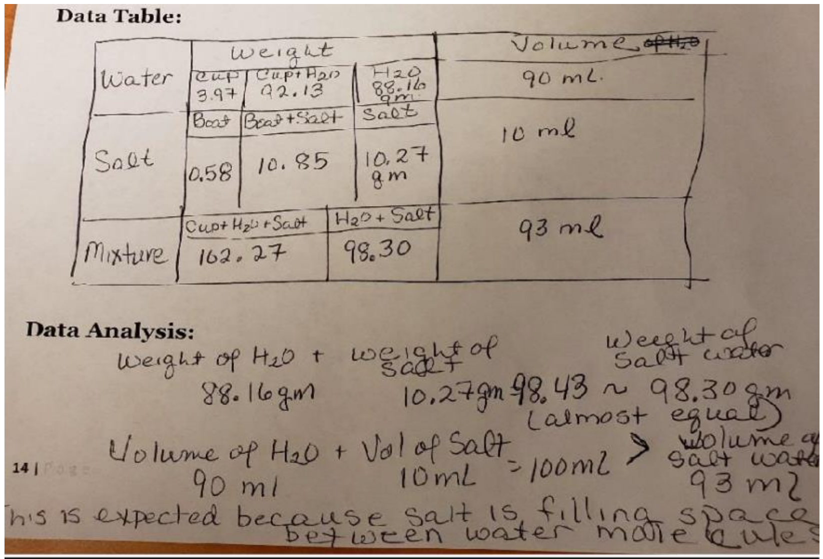
Ghost Particles

	Learning Goals for Lesson 4 ✓ Plan and carry out an investigation to show that the weight of a substance is conserved even when it is too small to see. ✓ Plan and carry out an investigation to show that the total weight of a system stays the same when one substance is mixed into another. ✓ Develop and refine models for systems containing particles too small to see.
Background Information for Performance Expectation	**Structure of Lesson** (LAUNCH) Students revisit the questions they generated about the anchoring phenomenon at the beginning of the unit. What new investigations could give evidence that could help explain the phenomenon? *DRIVING QUESTION: What investigations could give us new evidence about what happens when salt is added to water?* (EXPLORATION) Students plan and carry out an investigation and analyze the data to further explore what is happening when salt is added to water. *DRIVING QUESTION: How will we carry out our planned investigation to learn more about the salt + water system?* (SUMMARY) Students use evidence collected in their investigation to re-examine and possibly revise their models of the saltwater system. They then observe a new phenomenon (dots printed on a paper) that could possibly help explain the salt + water system. *DRIVING QUESTIONS: How does the data we collected and analyzed help explain what happens when the salt is stirred into the water? Are there similarities with a simple model of dots printed on a piece of paper?* **Science Content specific to Lesson 4** (terminology in bold is defined in the vocabulary section) When mixing two substances, the total amount of matter in the mixture is conserved. This is called the **Law of Conservation of Mass** (since the measure of the amount of matter is its mass (or weight)). In other words, matter cannot be created or destroyed (under normal conditions). The volume may not stay the same, as students will learn in Lesson 5. **Math Content specific to Lesson 4** Students will analyze data but will not be graphing until later lessons. **Educational Strategies introduced in Lesson 4** (see the background material at the beginning of the unit for more information) **Resources used in Lesson 4** The information on Slide 10 about reading volumes in graduated cylinders is adapted from a Math Trailblazers curriculum website, [Math Trailblazers (khmtb4.com)](khmtb4.com)

Ghost Particles

<u>Example of completed data tables</u>



Data Table:

	Weight			Volume ~~of H_2O~~
Water	Cup 3.97	Cup+H_2O 92.13	H_2O 88.16 gm	90 mL.
Salt	Boat 0.58	Boat+Salt 10.85	Salt 10.27 gm	10 ml
Mixture	Cup+H_2O+Salt 162.27		H_2O + Salt 98.30	93 ml

Data Analysis:

Weight of H_2O + weight of Salt   Weight of Salt water

88.16gm   10.27gm 98.43 ~ 98.30 gm (almost equal)

Volume of H_2O + Vol of Salt = 100mL > Volume of Salt water

90 ml   10mL   93 ml

This is expected because salt is filling space between water molecules

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TEACHER TIP*: The above example uses the graduated cylinder to measure volume. Students might also decide to measure the height on the cup with a ruler before and after adding salt. In either case, they should find that the volume increases, but it is not conserved. The weight should be conserved.*

Materials

Launch – *Students will work with page 16 of their notebook*

For each group of students (3)

- Talking Chip

Exploration *– Students will work with page 17 of their notebook*

For each group of students (3)

- Lesson 4 Task Card
- Any materials used from lessons 1-3
- 100ml graduated cylinder
- Water

Summary – *Students will work with pages 18-20 of their notebook*

For the classroom

- (Optional) Set of 3 labeled vials (sand/gravel)

For each pair of student

- Set of dot sheets
- Hand lens (1 per student)

Prior Knowledge

Students will be building on the investigative techniques they used in the scaffolded investigations of Lesson 3 to plan and conduct their own investigation about what happens to the salt when added to the water.

Ghost Particles

<table>
<tr><th colspan="2">Launch</th></tr>
<tr><td>Engagement:
Observing Matter</td><td>

DRIVING QUESTION: What investigations could give us new evidence about what happens when salt is added to water?

1. Ask students to turn to Page 15 of their Science Notebook and reread the ideas they had about the salt + water system. Refer back to the classroom list of questions students generated in Lesson 1 after exploring the salt + water system. Are there questions students can now eliminate, or other questions that need to be added?
2. What possible investigations could help us explore the phenomenon further and to answer the wonders they still have about what happened to the salt when it was added to water? Without talking or writing anything down, give everyone a few minutes to think about what investigation they could do to help explain this phenomenon. Picking one idea, students should quietly fill in the first row on Page 16 of their Science Notebook.
3. If possible, have students work with the same group of three they had for Investigation B of Lesson 3.
    a. Using a talking stick, give everyone a chance to explain their best idea to the rest of the group of three. Then, as a group, pick one idea to pursue, and write down the plan on the second row of the table (*Page 16*).

***Teacher Tip**: At this point students don't need to write a full procedure.*

b. Each group on the right side of the room will take their notebooks and go find a group on the other side of the room. The two groups will explain their plan, listen to the other group's plan, then everyone ask questions and discuss.

c. Returning to their seats, each group should discuss whether they want to make changes to their plan at this point. Did the other group have some good ideas your group may not have considered? Write the new plan in the third row of the table.

d. Each group report their plan to the rest of the class, as the teacher writes the ideas on the board. Can the class come to consensus on one or two investigations the class should try?

***Teacher Tip**: If necessary, guide the discussion towards the definition students have for matter, as well as the investigation just finished, so that students consider measuring weight and volume. It will take some discussion as a class on the best way to measure this. (Students could measure the height of the salt, the water, and the solution in identical cups, or they could measure volume in milliliters (ml).) They might come up with other equally good ideas.)*

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</table>

	***Teacher Tip**: If there are two investigations that the class wants to pursue, then assign which groups will do which investigation. It might be possible that groups measure two variables (e.g., weight and volume) in the same investigation.* • Give each student time to write the plan in their Science Notebook (fourth row).
Exploration	
Plan and Carry out an Investigation	*DRIVING QUESTION: How will we carry out our planned investigation to learn more about the salt + water system?* 1. (Slide 14) Let students know that they will have available all the supplies they have used previously, and additionally, a graduated cylinder to measure volume. The PowerPoint slide will show students how to measure the volume in a graduated cylinder. 2. Each group will plan their own procedure following the Lesson 4 Task Card. Have students flip to Page 4 of their Science Notebook and reread the Groupwork Norms. Within their group, students should switch roles from the previous lesson. Once the data collection is complete, all students can copy the data into their notebook and do the analysis together. ***Teacher Tip**: In order to get measurable data for both weight and height, an optimal amount of salt and water to use is about 10 milliliters (2 scoops) of salt per 90 milliliters (about a ½ full cup) of water. Students could measure change in volume by the height of the cup or by pouring the mixture back into the graduated cylinder. If there is time for more than one measurement, students might decide to use the amount of salt or amount of water as a variable for their investigation.* ***Teacher Tip**: If students choose to measure volume change by measuring the height change on a cup, please ask them to make any marks on masking tape so that the cups can be reused.* 3. After all the groups have finished analyzing their data, have a class discussion in which each group reports on their results and write them on the board. What did the groups learn about the change in weight of the system when the salt and water were mixed? The change in volume? Did all groups get the same result? If not, did some of the groups have technical problems? ***Teacher Tip**: Students should find that the weight of the salt + water system is the same as that of the salt and water when weighed separately. However, if they measure volume, they may notice that the volume of the salt + water is greater than the volume of the water alone but is less than the sum of both. Suggest that this is also evidence that should be considered as they refine their models in the next section.*

Ghost Particles

<table>
<tr><th colspan="2">Summary</th></tr>
<tr><td>Consolidation of Learning</td><td>
DRIVING QUESTIONS: How does the data we collected and analyzed help explain what happens when the salt is stirred into the water? Are there similarities with a simple model of dots printed on a piece of paper?

As a formative assessment, have students think about what evidence the data tells them about what happened to the salt when it was mixed into the water. Why did it seem to disappear? Is it still there? Individually, they should fill out the Claims- Evidence-Reasoning table in their notebook and draw a model (Page 18). This is the formative assessment for this lesson.
Each student will explain their new model to a partner. Do both students have similar claims of what happens to the salt, or are they very different ideas? Discuss some of the ideas that students came up with as a class and write the major claims on the board. Which claims are supported or refuted by the evidence collected in the investigation?
Next pass out one set of Now You See It, Now You Don't dot sheets to each pair, and give each student a hand lens. Students will examine the front and back and discuss with their partner what they are seeing. Individually, students will reflect on the two dot sheets by completing the 'I noticed…' statements in their Science Notebook (Page 19), and reflect on the similarities the dot laminations might have with the salt+water system by completing the 'I wonder…' and 'I think …' statements in their notebook.

TEACHER TIP: Each page of the dot lamination has the same number of dots. On Page 2, the dots are just spread out, making them very difficult to see. If students think Page 2 is blank, suggest that they might want to look with the hand lens they used earlier. There is a page number on each sheet so they know which is the printed side.
<ol start="4">
(Optional – material to be provided by teacher) If students are still confused about the volume data, show them the three cups – #1 has 5 cm of fine sand, #2 has 5 cm of gravel, and #3 has the two mixed. Why does the height of #3 not equal 10 cm?
(Optional) What will happen if the cups of salt water are left out? Students can label their cup with their group names, then save their saltwater solution on a shelf in the room (preferably a warm part of the room). When they come in on subsequent days, they can measure the height of the solution and make observations of its appearance to see if it changes over time. Alternatively, they can pour some of their saltwater into a flat container to make a shallow layer for the whole class to observe.

</td></tr>
<tr><td>New Terminology and Concepts</td><td>Law of Conservation of Mass –a statement that matter cannot be created or destroyed. The amount of matter (mass or weight) will stay the same whether it is mixed with something else or otherwise changed.</td></tr>
</table>

Ghost Particles

Connection to Big Ideas (DCI)	When two substances are mixed (salt + water), the weight of the combined system is equal to the weight of the salt plus the weight of the water, even though the salt seems to disappear. The salt does not go away, but it becomes undetectable with the eyes. The dot sheets, which show the effect of having tiny dots very close together versus spread out on the page, helps student visualize with is happening to the salt.
Assessment	Page 18 from Science Notebook (Claim-Evidence-Reasoning) and modeling.
Optional Extensions	The process of evaporation can be observed over the next several class periods using students' cups of salt water. See the optional Step 5 in the Summarize section. Evaporation will be explored in more detail in Lesson 5.

Ghost Particles

Lesson 5	What's Up with Air?
Three Dimensional Teaching and Learning	**Logistics.** *This lesson has many new concepts and may take two class periods for students to plan and carry out an investigation with multiple data points, then analyze and graph the data. The structure and flow of the lesson is given at the beginning of the Background Material section.* **Synopsis.** *Students are introduced to the lesson phenomenon of boiling water, plan and conduct investigations to show that air is matter, and learn that matter is made up of particles called atoms and combinations of particles called molecules. They apply their newly gained knowledge to the evaporation of salt water. Condensation can be introduced as an optional extension.* **Continuing to build toward** **5-PS1-1.** Develop a model to describe that matter is made of particles too small to be seen. **5-PS1-2**. Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved. **5-PS1-3.** Make observations and measurements to identify materials based on their properties. **Disciplinary Core Ideas** ✓ PS1.A Structure and Properties of Matter **Science and Engineering Practices** ✓ Planning and carrying out investigations ✓ Analyzing and interpreting data **Crosscutting Concepts** ✓ Scale, Proportion and Quantity **Associated SD Mathematics Standards** **5.MD.B.** Represent and interpret data. **Connecting to ELA and social studies** ✓ Throughout the unit, the use of Science Notebooks presents students with opportunities to practice and improve their writing and reasoning skills. ✓ The article, *Traditional Ways of Knowing: Salt Harvesting,* is a social studies reading tied to salt harvesting, to be introduced when students learn about evaporation.

Ghost Particles

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Driving Questions

- ✓ What happens when heat is added to water?
- ✓ What is air? Is air matter?
- ✓ Does a theory that all matter is made up of particles called atoms which are too small to see explain natural phenomena such as salt 'dissolving' in water, water boiling and properties of air?

Learning Goals for Lesson 5

- ✓ Ask questions and develop models about what happens to water when heat is added and the nature of air.
- ✓ Plan and carry out a class investigation to show that air has mass and takes up space.
- ✓ Analyze and interpret the data they collect through graphing data points and use it to draw conclusions about whether air is matter.

</td></tr>
<tr><td>Background Information</td><td>

Structure of Lesson

(LAUNCH) The gas phase is introduced through the lesson phenomenon of water boiling. Students ask questions and model the boiling water system, comparing it with the anchoring phenomenon (salt mixed with water).

DRIVING QUESTION: What happens when heat is added to water?

(EXPLORATION) The class will do an investigation to determine whether air has volume, and practice graphing skills as they analyze the data. Then groups will plan and conduct an investigation to determine whether air also has weight (mass).

DRIVING QUESTION: What is air? Is air matter?

(SUMMARY) Students use their reasoning skills to apply a model that air is made up of particles too small to see (atoms) to explain the phenomena experienced so far in this unit:

1. the disappearance of salt when added to water;
2. the disappearance of water when heat is added;
3. the fact that when heat is added to water, bubbles form.

DRIVING QUESTION: Does a theory that all matter is made up of particles called atoms which are too small to see explain natural phenomena such as salt 'dissolving' in water, water 'boiling' and properties of air?

(ASSESSMENT) Students apply their atomic model to a new phenomenon: What will happen when salt water is heated to boiling?

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Science Content Specific to Lesson 5

After investigating the macroscopic world, students will begin to study the properties of matter they cannot see, the **microscopic** world. By introducing the concept that matter is made up of **atoms** too small to see, students can model three **states of matter** - **solid** , **liquid** and **gas**. A **phase change** is the scientific terminology for when a substance is changed from one state to another due to heating or cooling. Some examples are **evaporation –** changing from liquid to a gas phase, and **condensation –** changing from gas to liquid phase.

Atoms are the basic building blocks of the macroscopic world, and there are approximately 100 different types (**elements**). All atoms are too small to be seen with the naked eye. Sometimes atoms combine to make larger structures called **molecules**. These are also too small to be seen with the naked eye. Air contains both atoms and molecules. There are about 10,000,000,000,000,000,000 (19 zeros!) atoms or molecules in 1 cubic centimeter of air. In a solid or a liquid there are so many more atoms bound together that the system becomes visible.

Educational Strategies used in Lesson 5

Think-Pair-Share

Resources for Lesson 5

1. The balloon demonstration you set up in class is shown on YouTube at https://www.youtube.com/watch?v=o5LT_wfl98w. We recommend you watch it before trying it in class.

2. PHET States of Matter Animation (https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html)

3. DESMOS (https://www.desmos.com) is a free website that has an easy-to-use graphing function.

4. (Optional reading) *Traditional Ways of Knowing: Salt Harvesting,* from Exploring our Fluid Earth (https://manoa.hawaii.edu/exploringourfluidearth/chemical/chemistry-and-seawater/salty-sea/traditional-ways-knowing-salt-harvesting).

5. (Optional) Properties of Matter video on Generation Genius, https://www.generationgenius.com/videolessons/properties-of-matter-video-for- kids/

Ghost Particles

<table>
<tr><td>Materials</td><td>(LAUNCH)
Note: Students will be working on pages 21-23 in their Science Notebook.
(EXPLORATION)
Note: Students will be working on pages 24-31 in their notebooks for the Exploration.
For each group of students (3 optimal)*
• A talking stick
• Lesson 5 Task Card
• Have the following items available on the materials table (with the laminated card on display with the group limit of individual items):
  • Small and large balloons
  • Balloon pumps
  • Wire hanger
  • Rulers (12” & 6”)
  • Heavy string (precut to 2 lengths)
  • Kite string (precut to lengths)
  • Rubber bands
  • Paper clips
  • Scissors^
  • Painters tape
  • Scotch tape
(SUMMARY)
Note: Students will be working with pages 28-30 for the Summary and Assessment for this lesson.</td></tr>
<tr><td>Prior Knowledge</td><td>Students may be familiar with gasses and know the fact that air is a gas. They probably haven’t thought about what that exactly means.
Students will be doing an investigation with dependent and independent variables and representing the data with a graph.</td></tr>
</table>

Ghost Particles

<table>
<tr><th colspan="2">Launch</th></tr>
<tr><td>Engagement:
Introducing Lesson Phenomenon and Connecting to Unit Phenomenon</td><td>

DRIVING QUESTION: What happens when heat is added to water?

BEFORE THE DAY STARTS

A. Figure out a place in the classroom to set up your meter stick balance (could hang from a cabinet or use the ring stand and clamp). Cut a piece of the heavy string the right length so that you can tie a loop around the meter stick and it will hang down with about 18” clearance from the table or floor. (You will put everything together during class.)

B. Blow up two (per class) of the small balloons from the kit to approximately the same size and tie them off with two identical lengths of strings and loops.

C. Designate a table or bench for a materials table for the Exploration and set out the materials, along with the laminated limit card.

1. (OPTIONAL) If the class is doing observations of the saltwater solution from Lesson 2, begin the class by checking the samples.
2. Remind students that in previous lessons, we were exploring properties of matter, and the definition that matter has weight and takes up space. In Lesson 3 we did two investigations about salt. Did the salt crystals fit our definition of matter? *Yes, they had weight and took up space.* In Lesson 4, we added the salt to water. Did the salt+water system fit our definition of matter even though we could no longer see the salt? *Yes, it had weight and took up space.* Today we are going to add to our understanding of matter and the salt+water system by examining water more closely.
3. (Slide) Students will watch two videos (linked from the PowerPoint) that show water as it is heated up to a boil. Tell students that they should focus on the water itself. What do they observe? The first video () is in slow motion and filmed from the side of a clear container. Play it through once while students watch, then play it again while they write what they observe in their Science Notebook (*Page 21*). Next show the second video (0.38 sec) through once, then replay it while students write their new observations in their notebook. This time students are observing the water from the top and at regular speed.
4. Then the class will use a Think-Pair-Share activity to come to consensus about wonderments they have about the phenomenon of boiling water *(Page 22)*. Remind students that they should think about what they observed carefully before writing anything down. After students have time to write down three wonderments they have, they should share with a partner and between them pick one to share with the full class.

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5. As each pair shares out their wonderment with the rest of the class, write them in a list on the board. Then have each student write down three they are interested in exploring further. Come to consensus as a class.

TEACHER TIP: You may have to focus the discussion by reminding students that the unit is about matter and its properties. Try to get students thinking in the direction of what is happening to the water as it leaves the pot in the form of steam.

6. How does this new phenomenon compare to the unit phenomenon (salt + water)? In order to make the connection, have students fill out the two statements on the bottom of Page 22, and discuss as a class.

7. Students should notice that the water seems to disappear into air. Refer to the list of questions about the boiling water phenomenon and circle any of them that are related to the water disappearing into the air? We have seen in previous lessons that water is matter – it has weight and takes up space? But what about when we add heat and the water 'boils away'? Does the water still exist? Is it still matter? And where has it gone? Ask students to think about it and to draw a model of what they think happens when heat is added to a pot of water (Page 23).
</td></tr>
<tr><td colspan="2" align="center">Exploration</td></tr>
<tr><td>Plan and Carry out an Investigation (PART A)</td><td>
DRIVING QUESTION: What is air? Is air matter?

1. In a class discussion, solicit student ideas about air. Write them on the whiteboard or chart paper.

TEACHER NOTE: Don't correct any student misconceptions at this point. Just write all the ideas down in a list without commenting, using the students' language. There will be an opportunity to circle back around.

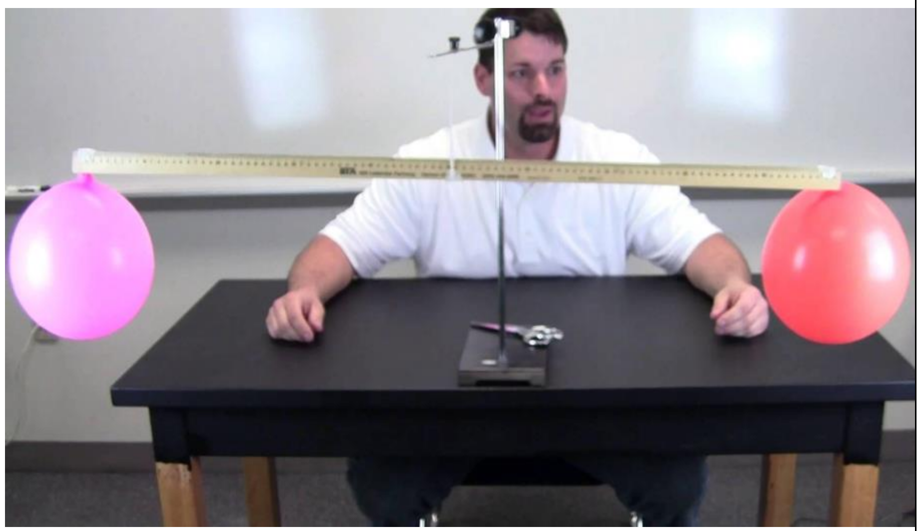
2. Is air matter? Does it have mass and take up space? Give the students a minute or two to think about whether or not air is matter and write a prediction in their notebook (Page 24). If they are not sure, that is okay:
a. A fist - they are absolutely sure that air is not matter,
b. 1 finger - that they are pretty sure that air is not matter
c. 2 fingers - that they are not sure but are leaning towards air is not matter
d. 3 fingers - that they are not sure but are leaning towards air is matter
e. 4 fingers - that they are pretty sure that air is matter
f. 5 fingers - that are absolutely sure that air is matter
</td></tr>
</table>

3. Countdown to a Fist to 5 to poll the class on what their choices were. Have students keep their prediction up while you randomly pick one student who has chosen each option to talk about why they chose that option. Student answers should refer to ideas about whether air has weight and volume (takes up space).
4. Have everyone in the class stand up, and on the count of 3 take one deep breath and hold it for a count of 5, then release it. Then have them close their eyes and take one more deep breath - holding it while thinking about what that tells them about air. Sit down and answer the 3-2-1 statements in their notebooks (*Page 24)* (3 things I noticed, 2 things I think, 1 thing I wonder…) about the process of breathing and air. Then students will share their notices and wonderments with their neighbor. Every pair on the left side of the room will choose one notice to share with the rest of the class, then every pair on the right side will share one wonderment. Write the wonders on the board to come back to.
5. Students should have noticed their lungs expanding as they breathed Have students write an explanation in their Science Notebook *(Page 25)* about whether or not this is evidence that air takes up space. Then they should think about three other pieces of evidence from the world around them that shows that air does or does not take up space, writing those in their Science Notebook (*Page 25)*. If they are having difficulty thinking of three, have them discuss with a partner. Finally, they should think about if there is also evidence from the world around them that air does or does not have weight, and write down their ideas.

TEACHER TIP*: It is not necessary to have the students in the same groups they were in for Lessons 3&4.*

6. Break the class into small groups (3 optimal). Each group should brainstorm ideas for using balloons to explore whether air is matter. Students may find it easy to think about how to use balloons to show air takes up space, but harder to think about weight. After they have talked for a few minutes, interrupt the discussion and ask what ideas they have had about weight. How can we figure out if air has weight (mass)? Solicit suggestions from the class. They might suggest weighing the balloon with the scale they used in Lesson 2. Try it with a small balloon. Weigh it empty, then pump it or blow it about half full and try to weigh again. Students should see that the scale isn't sensitive enough and it is hard to keep the balloon on the middle of the scales.
7. How about a more sensitive balance to measure weight? Ask students if they think the class could build their own balance to measure weight. Solicit their ideas, then show them one possible system.

NOTE TO TEACHERS: *Wherever you decided to set up the balance, demonstrate it for the class now. Slide one balloon with its string loop over each end of the meter stick. You can adjust the position to balance the scale; this will compensate for any differences between the two balloon/string combinations.*



8. Ask the students to think about what will happen if you pop one of the two balloons and have them circle their prediction on the diagram in their Science Notebook (*Page 26*). Then use the hatpin to carefully pop one balloon. *That side of the balance should tip up as the air leaves the balloon.* Have students draw what they observed to happen.
9. (Slide) Continuing with the same groups of three, students should use a talking stick to have each member explain what they think made the balance tip. Is this demonstration evidence that air has weight, or could something else be happening? Can they come to consensus as a group? Then poll the class individually; give them the options listed on the PowerPoint slide, then ask for another Fist-to-Five.
10. Give each group a few more minutes to brainstorm ideas, then pass out a What's Up with Air? Task Card. Before they start, remind students about the groupwork norms and have them flip back to Page 4 in their Notebooks to review them. Then give them time to read the Task Card and to plan an investigation to collect evidence for whether or not air is matter. The back of the Task Card has some ideas for how the measurement could be done.

Before they collect material, they need to demonstrate to the facilitator that they know:

a. What their independent variable is (what they will change systematically) and how will they change it;
b. What dependent variable will they measure to show whether or not air takes up space, and how will they measure it;
c. What dependent variable will they measure to show whether or not air has weight, and how will they measure it;
d. They each have a written procedure in their notebooks and does their procedure include a control, for example, an empty balloon.
e. Each student has labeled what will go in the three columns of the data table.

11. Each student in the group will be responsible for measuring one of the three variables. Then the group will work together to plot both sets of data. Grids are included in the Science Notebook for plotting both volume and weight data, but students will have to decide how to scale the x- and y-axes to fit their data. Alternatively, data could be plotted with a graphics program (EXCEL, DESMOS).

TEACHER TIP*: The volume graph is not going to be linear since students are not calculating the volume of the balloon, but both the radius and circumference will increase with the amount of air in the balloon. Likewise, for the weight measurement, the trend in the data will vary depending on how they decide to measure how much the hanger balance tips. (As the weight is increased, if they choose to measure the distance between the floor and the top of the balloon it will be a negative correlation, but if they choose to measure how much the hanger dips from horizontal (put the 0 cm on their ruler at the top), then it will be a positive correlation (go up with weight).*

12. Give everyone a few minutes to think about the data analysis and what it means. Does it support the claim that air takes up space, or not? They should use the matrix in their notebook (*Page 31)* to write down their evidence and reasoning for whichever claim they think is correct.
13. Each student will pair up with someone from a different group and compare their data, analysis and reasoning. Did they end up with the same conclusion. Why or why not? Share out with the full class. Can the class come to consensus about whether air is matter?

Ghost Particles

Summary	
Consolidation of Learning	*DRIVING QUESTION: If air is matter, what is it, and why can't we see it?* 1. (Slide 15-16) Air is made up of particles called **atoms** and combinations of atoms called **molecules**. One very important component (part) of air is oxygen (O_2). Our bodies use the oxygen and without it we could not survive. The different kinds of atoms are called elements. Each element has its own properties. We are made up of many different elements and molecules. 2. (Slide) Water is unique in that all three states of matter of a water molecule can be experienced in everyday life. At room temperature, is water a solid, liquid or gas? *You can demonstrate with this animation, or if there is time and enough computers, let students explore it on their own. Click on the link in the slide to get to the animation. (Linked from PowerPoint or go to* https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html). *Then click on the liquid button to show what the molecules are doing.* In a liquid, the atoms or molecules are close together but not too close. A liquid takes the shape of its container. What happens when we put the water in the freezer? *Click on solid to show how the molecules behave.* In a solid, the atoms are attracted to each other and stick together to become a substance that holds its shape without a container. It feels 'solid'. You can push your hand through liquid. What happens when we heat the water up to its boiling temperature? In a gas, the atoms and molecules are so far apart you are not able to see them, just like the dots on the pictures we saw in Lesson 2. *Click on gas to show how the molecules behave.* 3. Return to the lesson phenomenon of the steam disappearing into the air. Do students want to change their idea of what is happening to the water vapor? Have a class discussion. Then remind students that in Lesson 2 they dissolved a solid (salt) into a liquid (water). In Lesson 3 we saw that we can evaporate a liquid (water) into air (gas). For the formative assessment, students should draw a before and after diagram and write an explanation of what would happen if we boiled a pan of salt water. 4. (OPTIONAL) (Slide) Read the matter poem on the slide and discuss as a class. Does it accurately depict the three states of matter, solid, liquid and gas? 5. (OPTIONAL) As a final review of matter and properties of matter, watch the Properties of Matter video on Generation Genius, https://www.generationgenius.com/videolessons/properties-of-matter-video-for- kids/ . The video also introduces other properties not discussed in Lesson 1 (magnetism, density, solubility). Instructions for making slime are on the flash drive and can be given to students to take home for a family science activity.

	6. (OPTIONAL) An article is included on traditional harvesting of salt. This optional reading assignment could tie into social studies and be done either as homework or in class. A question set at the end of the article could be used for class discussion.
Terminology and Concepts to Solidify	**Atom –**the building blocks of the matter that our world is made of. Atoms are too small to be seen in regular microscopes. **States (phases) of Matter –** Matter can come in one of several states, also called phases. The ones we are most familiar with are solids, liquids and gases. **Solid –** In a solid, the atoms are attracted to each other and stick together to become a substance that holds its shape without a container. **Liquid –** In a liquid, the atoms or molecules are close together but not too close; a liquid takes the shape of its container. **Gas -** In a gas, the atoms and molecules are far apart and invisible. **Evaporation –**the transition between liquid and gas phase **Condensation -** the transition between gas and liquid phase **Molecule –**a combination of one or more types of atoms. For example, water has two hydrogen atoms and one oxygen atom in it. We write water as H_2O in scientific shorthand.
Connection to Big Ideas (DCI)	Air is made up of particles that are too small to see, but we have shown in an investigation that they have mass and take up space. Therefore, they are part of the matter that makes up our world.
Follow Up/Practice	For homework or during class (or maybe during social studies), have students read about how many cultures have utilized natural evaporation to harvest salt from ponds in *Traditional Ways of Knowing: Salt Harvesting,* from Exploring our Fluid Earth (https://manoa.hawaii.edu/exploringourfluidearth/chemical/chemistry-and-seawater/salty-sea/traditional-ways-knowing-salt-harvesting). A classroom set of the article is included in the kit.
Assessment	The formative assessment for this lesson is the diagram and explanation that students make in their notebook for the process of evaporation of salt water.
Optional Extension	Watch the *Properties of Matter* video on Generation Genius, https://www.generationgenius.com/videolessons/properties-of-matter-video-for-kids/ , which approaches the properties of substances from an atomic model. The video also introduces other properties not discussed in Lesson 1 (magnetism, density, solubility). Instructions for making slime are on the flash drive and can be given to students to take home for a family science activity.

Ghost Particles

<table>
<tr><th>Lesson 6</th><th>Making Atoms ‘Visible’</th></tr>
<tr><td>Three- Dimensional Teaching and Learning</td><td>

Logistics. *It should be possible to complete this lesson in one class period.*

Synopsis. *Students return to the size of things as they explore the atoms and molecules that make up matter. With a really, really powerful microscope, scientists can see atoms. For particles that are even smaller than atoms, scientists use indirect evidence to detect them. Can we model a detector that will show us when invisible particles are nearby?*
Students will build an electroscope, make observations and measurements, and develop simple explanations.

Building toward

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

5-PS1-3. Make observations and measurements to identify materials based on their properties.

3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

3-5-ETS1-1. Define a simple design problem reflecting a need or want that includes specific criteria for success and constraints on materials, time or cost.

Science and Engineering Practices

- ✓ Developing and Using Models
- ✓ Constructing Explanation and Designing Solutions

Crosscutting Concepts

- ✓ Scale, Proportion and Quantity
- ✓ Influence of Engineering, Technology, and Science on Society and the Natural World

Driving Questions

- ✓ How small is an atom?
- ✓ How can we use indirect evidence to show that air is made up of atoms and molecules?
- ✓ How does the behavior of the electroscope give us evidence that a rod is ‘emitting’ special, invisible particles?

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Ghost Particles

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Learning Goals

- ✓ Understand that things too small to see still have properties that can be indirectly observed
- ✓ Utilize engineering to construct a simple device to indirectly detect particles that are too small to see

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<tr><td>Background Information</td><td>

Structure of Lesson

(LAUNCH) In this lesson, students will explore quantity as they fathom how many atoms are in something almost too small to see, and what that implies about the size of an atom. They are introduced to (or review) scientific notation for very large numbers.

DRIVING QUESTION: How small is an atom?

(EXPLORATION) Students explore the limits of technology at the nanometer scale (the size of an atom) and build their own simple detector to explore how indirect evidence can give information about something that is too small to see.

DRIVING QUESTION: How can we use indirect evidence to show that air is made up of atoms and molecules?

(SUMMARY) Students use their detectors to draw inferences about an unknown source of invisible particles.

DRIVING QUESTION: How does the behavior of the electroscope give us evidence that a rod is 'emitting' special invisible particles?

<u>Science Content Specific to Lesson 5</u> (terminology in bold is defined in the vocabulary section)

In a speck of dust 0.01 millimeter in size, there are approximately a trillion (1,000,000,000,000) (12 zeros) atoms. If you were to pack a cubic centimeter of air with dust particles you might have a billion dust particles, or 1,000,000,000,000,000,000,000 (21 zeros!) atoms, and you can only see them in a bright sunbeam. In order to deal with the very large and very small numbers necessary to discuss atoms, students are introduced to **scientific notation**.

100+ years ago, scientists discovered that an atom isn't just a solid ball of 1/billionth of a meter in diameter; instead, it is made of smaller **subatomic particles.** The structure of an atom is a middle school standard and will only be introduced here on a very basic level. Students will learn that an atom consists of a tiny **nucleus** with other tiny particles called **electrons** orbiting it that define the size of the atom. Think about the size of the solar system being defined by the orbit of the furthest planet; too far out, and the gravitational force is so weak that the planet won't be captured into orbit. An atom is similar. The electrons have a negative **electric charge** and they are attracted to the nucleus, which has a positive electric charge, if they are within the range of attraction. It is the range of the force that defines the size of the atom, which is almost all empty space.

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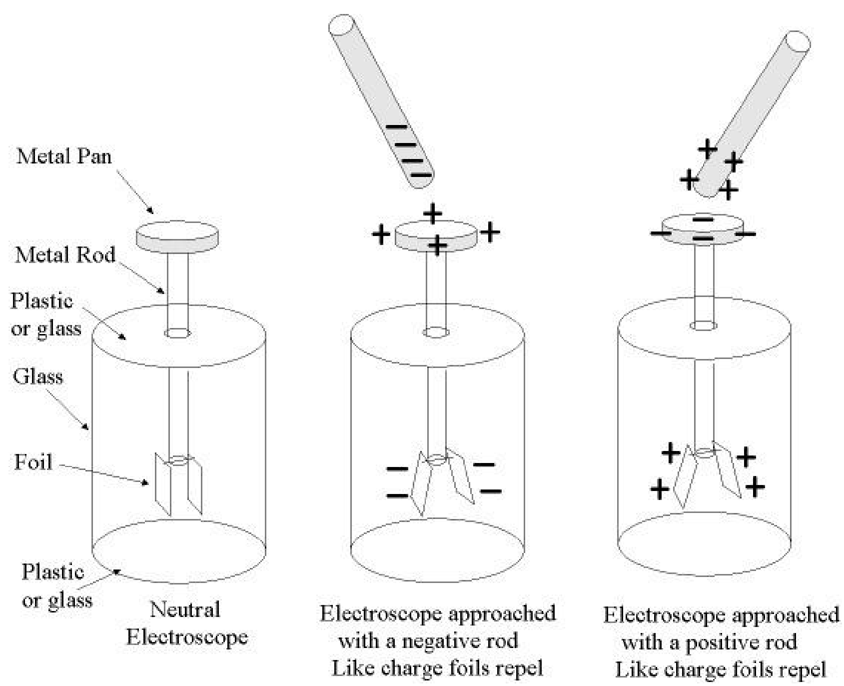
Scientists detect subatomic particles using **indirect evidence**, making **inferences** about what they cannot see to develop mental models*. For example, many observations - including the inflation and shape of a balloon; the effects of air on larger particles or objects (e.g., leaves in wind, dust suspended in air); and the appearance of visible scale water droplets in fog - can be explained with a model that gases (air, steam) are made from particles that are too small to see and are moving freely around in space.

An **electroscope** uses **static electric charge** to detect subatomic particles such as electrons and an atomic nucleus. It relies on the fact that like the poles of magnets, like electric charges repel each other and opposite electric charges attract each other. An electroscope is an example of a detector that uses properties of particles such as atoms to understand the structure and function of the particles.

Here is a diagram of a generic electroscope and what happens when it is approached by positive or negative charges.



Math Content Specific to Lesson 5

Scientific notation as a shortcut for writing a large number of zeros for either very large or very small numbers will be introduced in this lesson. On the large side, students will grapple with how many atoms are in a dust mote that is almost too small to see. Later in the lesson, as students explore nanoscales, scientific notation will be used for very small sizes.

	<u>Resources used in Lesson 4</u> ✓ Static electricity video from TED-Ed, https://www.ted.com/talks/anuradha_bhagwat_the_science_of_static_electricity ✓ The diagram above came from https://brainly.in/question/802316 ✓The activity in this lesson was adapted from http://queensu.ca/stepahead/english/content/science1/documents/labs_0809/1.7.1_electroscope.pdf ✓ This article from Carolina Science has a list of common materials used in science classrooms and which ones will tend to be positively charged (e.g., wool) and which ones negatively charged (e.g., balloon). https://www.carolina.com/teacher-resources/Interactive/the-triboelectric-series-an-introduction-for-static-electricity-labs/tr35107.tr ✓ A simulation of how an electroscope works can be seen at https://www.edumedia-sciences.com/en/media/742-electroscope (second tab).
Materials	***Launch*** - *Students will be work on pages 34-35 notebook* ***Exploration –*** *Students will work on page 36 of their notebook* For the classroom • Welding rod • Extra supplies (aluminum foil, balloon, paper clips) for multiple classes For each group of students (2) • Electroscope Task Card • Clear plastic cup with hole in top • 15-cm Ruler • Electroscope kit ○ Large Paper Clip ○ Aluminum Foil ○ Balloon ○ Wool Cloth ○ Comb • Scissors
Prior Knowledge	By the end of the first three lessons, students should have some comfort with the fact that matter can take the form of solid, liquid or gas and that it might be too small to be seen but that doesn't mean you couldn't see it with the right tools. Students should be familiar with the concept of electricity and static electricity from earlier grades. It is introduced here so that students can understand the devices they are building to indirectly detect atoms.

Ghost Particles

<table>
<tr><th colspan="2">Launch</th></tr>
<tr><td>Engagement: Scale and Quantity;</td><td>DRIVING QUESTION: How small are atoms and molecules?</td></tr>
<tr><td>Introducing Scientific Notation</td><td>
1. (Slide 23) Ask the class if anyone can think of any instances when we can see air or see particles in air. They may come up with fog, smog, dust storms or a beam of sunshine. Show some of these objects in the PowerPoint slide. Are they seeing the air particles, or something larger? What do they think?
2. Refer to the number line (which should be still on the wall). Ask students to remind you where a human hair fell on the number line. Approximately 0.1 mm How about the grains of salt they measured in Lesson 2, before grinding and after grinding? 1 mm and 0.1 mm Would they estimate that a dust particle in the air was larger or smaller than a grain of salt? Give students a minute to think about it, then take a poll of thumbs up (larger), thumbs down (smaller), or fist (the same).
3. (Slide 24-25) The next slide shows components of air pollution, called particulate matter, including dust and pollen particles, which are less than 10 micrometers (0.01 mm). Let’s think about one grain of dust. (click to bring up second image and again for the text box). With a really good balance, scientists can weigh one grain of dust and use the weight to calculate how many atoms and molecules are in that grain. Ask students to write a guess in their notebook (Page 34) of how many atoms are in the grain of dust. After discussion, show Slide 21 with the approximate answer. Guesses will vary wildly but it is unlikely that anyone will guess the correct answer: approximately a trillion (million-million) atoms.
4. (Slide 26) Using the PowerPoint, introduce the concept of scientific notation to denote very large numbers. Have students practice writing the numbers in the table in their notebooks (Page 34).
5. (Slide 27) So how small are atoms, if more than 10^{12} atoms are in one grain of dust? Show the Nanoscale video (linked in PowerPoint or on unit flash drive). NOTE: If played from PowerPoint the video will automatically stop at 3:08; otherwise stop it at that point. Students will learn from the video that to the nearest power of 10, atoms and molecules are on the scale of a nanometer (1/billionth of a meter).
6. Give students a few moments to use sentence frames to write four things they noticed/learned/thought/wondered about the video in their Science Notebook (Page 35). Afterwards, ask for volunteers to read something they wrote down that had to do with the size of atoms. Do they have questions still about how scientists can see atoms? Discuss as a class.
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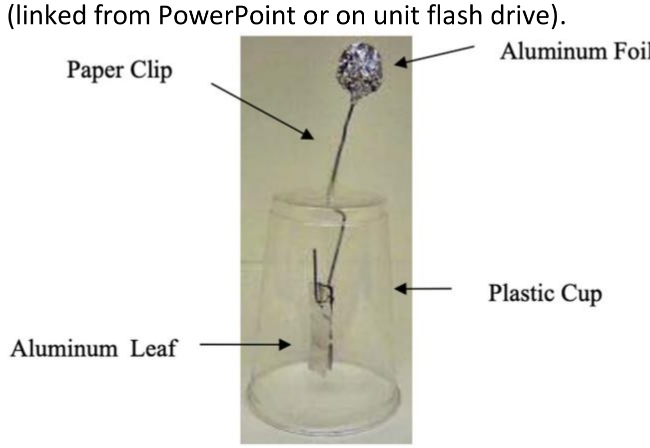
	7. (Slides 28-29) Scientists and engineers have developed powerful microscopes that can see atoms at the scale of nanometers. The scientist in the video was standing in front of one such instrument, a **scanning electron microscope (SEM)**. If we don't have the space, money and expertise to build an SEM to see atoms directly, is there still a way that we can detect atoms in the classroom? (Slide 25) Have a discussion of what **indirect evidenc**e is and how it could be used to measure something that is too small to be seen. We made *direct measurements* in Lesson 3 that air has weight and takes up space, thus is made of matter. What kinds of *indirect evidence* do we have that air is made of particles? Have students write some ideas in their notebook, then share with a table or class discussion. 8. After the discussion, give students time to write in their notebooks their own definition of indirect evidence. ***TEACHER TIP****: While students are watching the video, add 4 more powers of 10 to the left-side of the timeline to get down to 1 nanometer.*
Exploration – *Indirect Evidence*	
Utilizing Technology to Make Atoms Visible	*DRIVING QUESTION: How can we use indirect evidence to show that air is made up of atoms and molecules?* 1. (Slide) We are going to construct a detector (called an electroscope) that can measure particles indirectly. Electroscopes were used by Marie and Pierre Curie in their famous experiments on atoms. An electroscope works by using a property of atoms that everyone should be familiar with called **static electricity**. Before we build the detector, called an **electroscope**, let's review what static electricity is through a video from TED-ED (linked from PowerPoint or on unit flash drive).  2. Organize the class into pairs, and pass out a Lesson 6 Task Card and a bag of materials to each pair. Following the instructions on the task card, give students a few minutes to put their electroscope together.

	3. Once students have built their electroscopes, the task card suggests several things students can try to see if their electroscope works. If they add or subtract electric charge from the electroscope using the items in their bag, what changes do they see? Have students choose one method for changing the charge and draw and write an explanation in their notebook of what is happening. 4. Now hold up a 'magic wand' (welding rod). Ask students to predict what will happen when they put the magic wand close to the top of electroscope. After students write down their predictions in their notebook (*Page 34)*, circle around to each group and let them try the experiment and draw and write their observations.
Summary	
Consolidation of Learning	*DRIVING QUESTION: How does the behavior of the electroscope give us evidence that a rod is 'emitting' special invisible particles?* 1. Facilitate a class discussion as to what students observed. Does anyone have an explanation for the behavior of the electroscope when the magic wand is brought close to the aluminum foil leaves? 2. (Slide) A few of the atoms in the welding rod have a special property that they 'emit' (give off) particles that are the 'nucleus' of an atom, missing the electrons. This makes them positively charged. These special particles will gobble up nearby electrons and change the repulsive charge between the two surfaces of the electroscope, so the electroscope can detect these special particles even though they are even smaller than an atom! When scientists use indirect evidence to study matter, they use the properties of atoms as tools.
Terminology and Concepts to Solidify	**Scientific Notation -** a mathematical shorthand for writing very large or very small numbers by writing it as a number between 1 and 10 multiplied by a power of 10, written as $10^{\wedge power.}$ For example, 1000 = 10^3 in scientific notation. For numbers less than 1, the superscript is negative. For example, 1 mm = 0.001 meters = 10^{-3} meters. **Micrometer –**a metric unit of length, equal to one millionth of a meter, 10^{-6}. **Scanning Electron Microscope (SEM) -** a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing signals that contain information about the surface topography and composition of the sample. A SEM can image individual atoms in a solid. **Nanometer –**a metric unit of length, equal to one billionth of a meter, 10^{-9}.

Ghost Particles

	Particles - tiny bits of microscopic matter that make up everything in the universe. There are many different types of particles, with different particle sizes and properties. **Subatomic particle –** Particles that are smaller than an atom are called subatomic particles. Atoms are made up of three types of subatomic particles – electrons, protons and neutrons. **Inference –**a conclusion reached on the basis of evidence and reasoning. **Indirect Evidence –**is a claim about an object or phenomenon that is based on inference. **Electron –**a stable subatomic particle with a charge of negative electricity, found in all atoms and acting as the primary carrier of electricity in solids **Electric Charge –**a fundamental property of particles. Charge can be either negative, positive or neutral. Electric charge is associated with the electromagnetic force, and like magnets, two particles with electric charges of opposite signs are attracted to each other and two particles with electric charges of like signs are repelled. **Static electric charge (static electricity) –** Static electricity is an imbalance of electric charges within or on the surface of a material. The charge remains until it is able to move away by means of an electric current or electrical discharge. **Conductor** –a material that has loosely bound electrons that move around easily. **Insulator** –a material that has tightly bound electrons that will not move easily. **Electroscope –**an early scientific instrument used to detect the presence of static electric charge on a body.
Connection to Big Ideas (DCI)	Even though atoms and molecules are too small to see with our eyes, with technology we are able to either see them directly, or detect them through their properties (e.g., static electricity).
Follow Up/Practice	
Assessment	The formative assessment for this lesson is the student's notebook explanations (Page 34) of what is happening between the electroscope and the welding rod. Explanations will be qualitative.

Ghost Particles

Lesson 7	A Ghost Particle
Three Dimensional Teaching and Learning	**Logistics.** *This lesson should take one class period. It can be replaced by a visit from a member of the (SURF) Underground Research Facility Education team.* **Synopsis.** *Students will learn about the tiniest particle that scientists have discovered in nature, a neutrino. They will construct an explanation that brings together scale, proportion, and quantity to construct an explanation for why it takes very large detectors to make a neutrino 'visible', then learn about the Deep Underground Neutrino Experiments at SURF.* **Building toward** **5-PS1-1.** Develop a model to describe that matter is made of particles too small to be seen. **3-5-ETS1-1.** Define a simple design problem reflecting a need or want that includes specific criteria for success and constraints on materials, time or cost. **Science and Engineering Practices** ✓ Developing and Using Models ✓ Using mathematics and computational thinking **Crosscutting Concepts** ✓ Scale, Proportion and Quantity ✓ Influence of Engineering, Technology, and Science on Society and the Natural World **Learning Goals** ✓ Students will understand that the tiniest particle in the universe, the neutrino, is also the most abundant, and that only the fact that there are SO many of them makes it possible for scientists to study them. ✓ Students will develop a model for why a neutrino passes through matter without interacting most of the time and why very large detectors are needed to investigate neutrinos. ✓ Students will learn about the Deep Underground Neutrino Experiment at the Sanford Underground Research Facility.

Ghost Particles

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<td>Background Information</td>
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Structure of Lesson

(LAUNCH) Students are introduced to one model of the size and structure of an atom through direct instruction (video) followed by group discussion.

DRIVING QUESTION: How small is an atom, really?

(EXPLORATION) Students develop their own models of an atom at several scales.

DRIVING QUESTION: How can we build a mental model that helps us to understand the smallness of an atom and its parts?

(SUMMARY)

DRIVING QUESTIONS: Are there any objects smaller than the nucleus and electron in an atom? How small is a neutrino and is it matter?

Science Content specific to Lesson 7

Ghost Particles is a descriptive nickname given to **neutrinos,** the smallest and most abundant particle in the universe, based on our current understanding. Somewhere buried deep inside the nucleus are the elusive neutrinos that are studied at the **Sanford Underground Research Facility**.

Math Content Specific to Lesson 7

Scientific notation was introduced in Lesson 6 for large numbers. In this lesson, students will practice science notation for very small numbers as they explore the size of subatomic particles.

References and Interesting websites

Fermi National Accelerator Lab (Fermilab), All about neutrinos website, https://neutrinos.fnal.gov/

Scientific American, https://www.scientificamerican.com/article/what-is-a-neutrino/

Smithsonian Magazine, November 2010, https://www.smithsonianmag.com/science-nature/looking-for-neutrinos-natures-ghost-particles-64200742/

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Ghost Particles

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<tr><td>Materials

Teacher Note: At the beginning of this lesson, add the rest of the number line sheets to the number line. You will be adding powers of 10 on both sides. (It will seem like lots of extra sheets, but it will make the modeling activity much easier.)</td><td>Launch -Students will work on page 38 of their notebook

For group of students (6/7)
• Talking stick

Exploration – Students will work on pages 39-40 of their notebook

For the classroom
• Meter Stick
• 10-meter rope
• Laminated atom, nucleus, electron, neutrino cards
• Blue painters tape
• Salt (1 grain)
• Small sticky notes

For each pair of students
• Modelling an Atom Task Card
• Marble
• 30-cm ruler
• Map of Levi Stadium (49ers)
• Two sticky notes

(Optional Activity) for small group (3/4)
• Ball of string
• Meter stick
• Grain of salt

Summary – Students will work on pages 37-38 of their notebook as they learn about neutrinos and reflect on what they have learned.
• All About Neutrinos Poster
• Colored Pencils (share)</td></tr>
<tr><td>Prior Knowledge</td><td>In the previous lessons, students made the conceptual change in ideas about the structure of matter. They now know that matter is made up of atoms too small to see.</td></tr>
<tr><td colspan="2">Launch (15 minutes)</td></tr>
<tr><td></td><td>DRIVING QUESTION: How small is an atom, really?

1. (Slide) Review with students the size of an atom (1 nanometer) and how many atoms are in something as small as a grain of dust (1 trillion). Note that we can use scientific notation for very small numbers, also, such as the size of an atom. Have students fill out the table in their Science Notebook (Page 38) to practice, then circle the row closest to the size of an atom.</td></tr>
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	2. (Slide) Play the first 3:19 of the video (linked from PowerPoint) *How Small is an Atom? (Ted-Ed). The video will stop automatically if you play it from the PowerPoint.* When they are done, they will use sentence frames to write in their notebook (page 35) things they learned or wondered about during the video. 3. Divide students randomly into four groups and have each group sit in a circle (keeping their notebooks with them for reference). Pass out a talking stick to each group. Remind students that they can only talk when they have the stick and it will be passed around the circle. If they don't have anything to add to the conversation when they get the talking stick, they can hold onto it for 10 seconds. If they still haven't thought of something to add, they can then pass it. a. The first time around the group, students should note something they LEARNED from the video content. b. The second time around the group, students should note something they THOUGHT about the video content. c. The third time around the group, students should note something they WONDER about after watching the video.
Exploration	
Develop and Use a Model	*DRIVING QUESTION: How can we build a mental model that helps us to understand the smallness of an atom and its parts?* 1. The video describes the nucleus of an atom as being the size of a small marble if the atom is the size of a football field. What does that mean? Can we use it to figure out how much smaller the nucleus is than the atom? Have students work in pairs and pass out a *Modeling an Atom* task card, a marble, a ruler, a Google Earth screenshot of a nearby football field, and two sticky notes. Students will measure the marble and write the size on one sticky note (to the nearest power of ten). Then they will do the same thing with the map of the football field. They will have to use the legend to determine how much to multiply their measurement by. 2. When each team is done with Model A, they can stick their sticky notes on the corresponding unit of the number line. If they have done the math correctly, every group should end up in the same place (*1 cm for marble and 100 meters for football field).* Then ask for two volunteers. Give one volunteer the atom lamination and have them stand by the point on the number line that was the actual size of the atom (1 nanometer). Then have the second volunteer start at the size for their model (100 meters). Have him/her walk down tapping each order of magnitude while the rest of the class counts. How many powers of 10? (*11*). That means that the 'marble' nucleus is scaled up 11 powers of 10 also. Have a third volunteer start at the yellow sticky notes with the laminated nucleus, then walk

	down 11 powers of 10 while everyone counts. This is the actual size of the nucleus: 10^{-13} meters (100 picometers). Tape the laminated atom and nucleus onto the number line and everyone sit down. Have students fill in the information under Model A in their notebooks (*Page 39)* 3. (Optional) Students can add the electron to their model. The size of an electron is 10^{-15} meters. So even in Model A, the scaled up electron would be too small to see. A laminated electron card is included for the number line. Scaling the electron will be included in Part B of the modeling activity when students scale up a neutrino. 4. Can we make a model of an atom in the classroom? Have students fill out their notebooks for Models B & C, to figure out the scaling. Then make Model B on the task card (10 meter diameter) in the classroom or on the playground. A 10 meter diameter rope is in the kit. Use it to help students stand in a circle 10 meter in diameter. Once they are there, take one grain of salt (1 mm) and set it in the center of the circle (the center is marked on the rope with a piece of white tape) 5. (Optional) If time permits, small groups of students can also make a model of an atom that is one meter across (Model C on Task Card), using string. They will have to crush a piece of salt to make a nucleus that is 0.1 mm. 6. Ask students what is in between the nucleus and the edge of the atom? They should remember from the video that is almost all empty space. Have them try to draw a scale model of an atom in their notebooks (*Page 40).* If the nucleus is a tiny dot, how large would the paper have to be to include the whole atom, if they wanted to draw it to scale?
Summary	
Consolidate Learning: Connections to SURF (neutrinos)	*DRIVING QUESTIONS: Are there any objects smaller than the nucleus and electron in an atom? How small is a neutrino and is it matter?* 1. (Slide) Scientists think that the tiniest particle in the universe is approximately another 11 powers of 10 smaller than the nucleus of an atom. It is called a neutrino. If students continued the classroom number line down another 11 powers of 10, approximately where in the classroom would that fall? Ask for a volunteer to start at the nucleus on the number line and step it down. Neutrinos are so tiny that scientists call them ghost particles. Add the laminated cartoon of a neutrino. 2. (Slide) Students can use the *Magnifying the Universe* (https://scaleofuniverse.com/en) app on their own or classroom devices *(we recommend muting the music with the button on the top right)*. First find the atomic scale at 1 nanometer. Then move down to the nucleus scale at 10^{-13} meters, and finally the neutrino scale at the 10^{-24} (yoctometer) scale.

***TEACHER TIP**: (2021) This app replaces the Scale of the Universe 2 that was used in previous versions because the former one used Flash. The new app is basically the same thing; the only difference we noticed is that the power of 10 in the corner is given in the form of a wheel.*

3. Have pairs do PART B of the Lesson 7 Task Card and fill out the table in their notebook (*Page 41*). If we made a model of the atom that included a neutrino, we could scale up so that the neutrino was the size of a crushed grain of salt (0.1 mm). The scale factor would be 10^{20}, so the nucleus would be 10^{7} meters, and the atom would be 10^{11} meters. Then use the *Scale of the Universe 2* to pick out something at the 10^{7} and 10^{11} scales to model the nucleus and the atom, respectively. *10^{7} is approximately the size of the earth. 10^{11} is the distance from the earth to the sun. So the nucleus would be the size of the earth, and the atom would be at the distance of the sun.*
4. If a neutrino is so very tiny, how can we possibly know it exists? Pass out a neutrino poster to each student. Give students a couple of minutes to look over the poster, pointing out the eight properties and adjectives used to describe these particles (fundamental, abundant, elusive, oscillating, lightweight, diverse, mysterious, very mysterious). Are there any of these words they are unfamiliar with and need a definition? If so, discuss them as a class.
5. Have students imagine a neutrino the size of a crushed grain of salt zipping through an atom the size of the distance to the sun. What properties of neutrinos make scientists think they can actually detect them? Using Think-Pair-Share, have students read the poster and think about this question then discuss with someone close to them. Which property or adjective(s) might make it possible to detect neutrinos? After pairs decide on an answer, share out with the rest of the class.
6. (Slide) Scientists know that the 'probability' that the neutrino will hit the nucleus of an atom is very tiny but not zero. And when it does, it will transfer some kinetic energy. The slide shows the first neutrino event ever seen in a hydrogen bubble chamber. With a very sensitive detector, we <u>may</u> be able to detect that energy. So they tried that with early detectors and were able to see evidence that a neutrino had come through.
7. (Slide) Scientists realized that a lot of larger particles made so many more tracks in their detectors that they couldn't find the neutrinos, so they decided to go deep underground to get away from this 'background'. The earliest underground neutrino detector was built right here in South Dakota at the Homestake gold mine.

Ghost Particles

	8. (Slide) Scientists have been building bigger and bigger detectors to try to understand neutrinos better. The Deep Underground Neutrino Experiment, coming to South Dakota in the future, is going to be the biggest detector in the world when finished. Show the DUNE video (from PowerPoint). 9. (Slide) Are neutrinos matter? In the studies scientists have done, they have shown that neutrinos have weight (although it is so small they haven't yet been able to measure what it is) and have size, as we have seen. So, yes, neutrinos are part of the matter of our universe. 10. Remind students that the chances that we will ever build something to directly 'see' neutrinos is extremely small, almost as small as a neutrino. But using their imaginations, now that they know something about these ghost particles, let them decorate the box on the front of your science notebook with what they think a neutrino (or neutrinos might look like). 11. Have students fill out the reflection questions on pages 42-43 in their notebook. This is the final assessment for the unit.
Terminology and Concepts to Solidify	**Nucleus of an atom –** The nucleus of an atom is in the center, positively charged, and contains most of the mass of the atom. Electrons are found in orbitals around the nucleus. The nucleus of an atom is 10^{-13} meters in diameter, compared to 10^{-9} meters for the whole atom. *In this unit, the fact that the nucleus contains positively charged protons and neutral neutrons is not introduced. If using at a secondary level, this can be discussed.* **Neutrino –**a subatomic particle that is emitted from the nucleus of an atom when it undergoes radioactive decay. Neutrinos can also be produced in particle accelerators. Neutrinos are the smallest (10^{-24} meters) and most abundant (62 billion / cm^2) particle that scientists have discovered. A neutrino is referred to as a ghost particle because billions of them are passing through us all the time and we can't feel them.
Connection to Big Ideas (DCI)	While we can't draw a model of an atom that is to scale, we can build a mental model by imagining a scaled up version. This is a technique used in science extensively. Even a particle as tiny as a neutrino can be scaled up to a size we can see, which would make the atom
Assessment	Final reflection
Optional Extension	Students can include electrons in their model. An electron is 1/100 the size of the nucleus (10^{-15} m). A laminated electron card can be used for the modeling activity.

Print Masters

FRONT OF PAGE 1

FRONT OF PAGE 2

FUNDAMENTAL

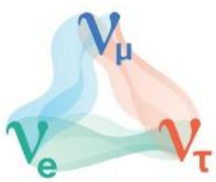
Neutrinos are fundamental particles, which means that—like quarks and photons and electrons—they cannot be broken down into any smaller bits.

ABUNDANT

Of all particles with mass, neutrinos are the most abundant in nature. They're also some of the least interactive. Roughly a thousand trillion of them pass harmlessly through your body every second.

ELUSIVE

Neutrinos are difficult but not impossible to catch. Scientists have developed many different types of particle detectors to study them.



OSCILLATING

Neutrinos come in three types, called flavors. There are electron neutrinos, muon neutrinos and tau neutrinos. One of the strangest aspects of neutrinos is that they don't pick just one flavor and stick to it. They oscillate between all three.

LIGHTWEIGHT

Neutrinos weigh almost nothing, and they travel close to the speed of light. Neutrino masses are so small that so far no experiment has succeeded in measuring them. The masses of other fundamental particles come from the Higgs field, but neutrinos might get their masses another way.

DIVERSE

Neutrinos are created in many processes in nature. They are produced in the nuclear reactions in the sun, particle decays in the Earth, and the explosions of stars. They are also produced by particle accelerators and in nuclear power plants.

MYSTERIOUS

Neutrinos are mysterious. Experiments seem to hint at the possible existence of a fourth type of neutrino: a sterile neutrino, which would interact even more rarely than the others.

VERY MYSTERIOUS

Scientists also wonder if neutrinos are their own antiparticles. If they are, they could have played a role in the early universe, right after the big bang, when matter came to outnumber antimatter just enough to allow us to exist.

Interested in how the universe works? Read *symmetry*, an online magazine about particle physics and its connections to life and other areas of science. Published by Fermi National Accelerator Laboratory and SLAC National Accelerator Laboratory. symmetrymagazine.org

symmetry | U.S. DEPARTMENT OF ENERGY | Office of Science

Ghost Particles Refurbishment Inventory (1/2)

Lesson	*Quantity*	*Item*	
Multiple	1	Facilitator Binder w/ USB	
	1	Shipping Tote	
	1	Salt (Tupperware)	
	10	Blue Painter's Tape	
	15 bundles of 5	Colored pencils	
	1	5 decimeter stick	
	15	30cm/12inch rulers	
	15	15cm/6inch rulers	
	10	Talking Sticks (binder)	
Lesson 1	1	20oz Cup	
	1	Vial of Salt	
	15	Lesson 1 Task Card	
	15	Marked Cup/Beaker	
	15	Plastic spoon/stir stick	
	15	5ml scoop	
Lesson 2	15	Size of Things Kit	
		(10) Decimeter strips	(10) yellow squares
		Paper cm squares	.1mm wire in bag
	15	Handheld microscope	
	30	Lesson 1 Exit Card	
	30(+)	Index Cards	
	30	Black Scale Plate	
Lesson 3	1 set	Small measuring spoons	
	15	Lesson 3 Task Card (A & B)	
	50(+)	Weigh Boats	
	10	Science Seminar Task Card	
	1 Box	Toothpicks	
	30	Lesson 3 Materials Bag	
		Spoon	toothpick
		Hand lens	
	4	Digital scale	
Lesson 4	10	Lesson 4 Task Card	
	10	100ml graduated cylinder	
	1 set of 3	Vials of sand & gravel	
	15 set of 2	Laminated dot sheets	
Lesson 5	1	T pin (binder)	
	10	Lesson 5 Task Card	
	Multiple	Large Balloons	
	5	Balloon Pump	
	10	Wire Hangers	
	10	Precut string (2 lengths)	
	Bag	Rubber Bands	
	Box	Paperclips	

	1	Resource Limit Card
	Multiple	Small Balloons

Lesson	*Quantity*	*Item*	
Lesson 6	1	Welding Rod (binder)	
	15	Lesson 6 Task Card	
	15	20oz cup w/ hole in bottom	
	15	Lesson 6 Material Bag	
		Large Paperclip	Aluminum foil sheet
		Balloon	Wool cloth
		comb	
	1	Aluminum foil roll	
	Box	Extra large paperclips	
Lesson 7	1	10 meter rope	
	1 set of 7	Laminated cards	
	15	Lesson 7 Task Card	
	15	Marbles	
	15	Map of Football Stadium	
	Multiple	Small sticky notes (two colors)	
	2 rolls	String	
	15	Neutrinos Poster	