

5

What's in Your Water?



A Collaboration of the K–12 Alliance @ WestEd,
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Grade 5 What's in Your Water?: Introduction

The California K–8 NGSS Early Implementation Initiative was developed by the K-12 Alliance at WestEd with close collaborative input on its design and objectives from the California State Board of Education, the California Department of Education, and Achieve. This project was designed to build local education agency (LEA) capacity to fully implement the Next Generation Science Standards (NGSS) as a core subject in the elementary grades (K–5) and as the SBE's preferred integrated model in grades 6–8.

The six-year Initiative provided teachers and administrators with in-depth, content-rich professional development to build leadership capacity and teacher acumen to deliver high-quality 3-dimensional learning for K–8 students. In addition, through collaborations among the K-12 Alliance, Achieve, and others, the LEAs in the Collaborative had opportunities to pilot test new NGSS-aligned tools, processes, assessment item prototypes, and digital and other instructional materials. The LEAs continue to serve as resources for NGSS implementation across California, and in other NGSS-adopting states as well.

This resource presents the conceptual storyline for a unit of instruction at a specific grade level, then focuses on a portion of the storyline called a learning sequence. The learning sequence uses the three dimensions of the NGSS (disciplinary core ideas—DCI; science and engineering practices—SEP; and crosscutting concepts—CCC) to build and deepen student understanding of natural phenomena and design challenges.

Participants in the CA NGSS K–8 Early Implementation Initiative developed and field-tested the lessons in the learning sequence.

Overview

This engineering design learning sequence is built on the anchoring phenomenon: Sewage water is consumed by people, but they do not get sick. Students are introduced to town water samples that have been gathered from a local town. The town hires the students to find out what is in the water and tell the town how to clean it. Students explore matter and its properties and discover that matter can be identified and grouped by its properties. Properties include size, shape, color, magnetism, conductivity, and solubility. They investigate quantifying matter by weight and volume. Using their understanding of physical properties, students design a solution to determine what is in the town water samples.

This unit builds towards these Performance Standards:

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

- PS1-3** Make observations and measurements to identify materials based on their properties.
- 3-5-ETS1-1** Define a simple design problem reflecting a need or want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of a problem.

Learning Sequence Narrative

The Learning Sequence Narrative briefly describes what students do in each lesson and links the learning between the lessons as a conceptual storyline. As students progress through the learning sequence, they are making sense of designing a solution to the problem.

The identified problem for this learning sequence is: Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water. Students begin thinking about a solution to the problem by developing models of the town water samples and exploring the properties of the observable and unobservable matter in those samples. The properties students explore include magnetism, conducting electricity, solubility, and the quantities of matter in terms of weight and volume. Students then design a solution and evaluate the efficiency of processes to clean the water samples.

Students figure out this phenomenon by:

Science and Engineering Practices (SEPs)

Asking Questions and Defining Problems

- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes criteria for success and constraints on materials, time, or cost.
- Use prior knowledge to describe problems that can be solved.

Developing and Using Models

- Develop and/or use models to describe and/or predict phenomena.
- Identify limitations of a model.
- Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.

Planning and Carrying Out Investigations

- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
- Evaluate appropriate methods and/or tools for collecting data.
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
- Test two different models of the same proposed object, tool or process to determine which better meets criteria for success.

Analyzing and Interpreting Data

- Analyze and interpret data to make sense of phenomenon, using logical reasoning mathematics, and/or computation.
- Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
- Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.

Constructing Explanations and Designing Solutions

- Apply scientific ideas to solve problems.
- Use evidence (e.g., measurements, observations, patterns) to construct of support an explanation or design a solution to a problem.
- Identify the evidence that supports particular points to an explanation.
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

Engaging in Argument from Evidence

- Compare and refine arguments based on an evaluation of the evidence presented.
- Construct and/or support an argument with evidence, data, and/or a model.
- Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions
- Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

Obtaining, Evaluating, and Communicating Information

- Read and comprehend grade-appropriate complex text and/or other media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.
- Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.

Disciplinary Core Ideas (DCIs)

PS1.A: Structure and Properties of Matter

- 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.
- Measurements of a variety of properties can be used to identify materials.
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish.

ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

ETS1.B: Developing Possible Solutions

- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

Crosscutting Concepts (CCCs)

Scale, Proportion, and Quantity

- Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

Patterns

- Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rate of change for natural phenomena and designed products.
- Identify patterns related to time, including simple rates of change and cycles and use these patterns to make predictions.

- Identify similarities and differences in order to sort and classify natural objects and designed products.
- Matter is made of particles and that energy can be transferred in various ways and between objects.

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change.

System and System Models

- A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.

Influence of Engineering, Technology, and Science on Society and the Natural World

- People's needs and wants change over time, as do their demands for new and improved technologies.

Throughout the sequence, students drive the learning and are expected to be the architects of their own sensemaking. The teacher facilitates this process by offering opportunities for questions, supporting, and redirecting when necessary.

Throughout the sequence, a flag (▶) denotes formative assessment opportunities where instruction may change in response to students' level of understanding and making sense of the problem. The sequence also provides direction when summative assessment opportunities arise.

Each individual lesson's narrative is based on the conceptual flow found at the end of this section.

Identified Problem: Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water.

Lesson 1: Town Water Samples

This lesson is the first in the sequence and is designed to engage students' prior experience with contaminated water, elicit their questions about contamination from observations of a video and actual water samples, and generate investigation questions that will drive their learning through the next set of lessons. This lesson introduces the identified problem: Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water. In order to do this throughout the learning sequence, students will build on their prior knowledge that matter is made of particles too small to be seen, but even then, the matter still exists and can be detected by other means.

Lesson 2: Finding Impurities in Water

In this lesson, students use their investigation questions to identify the presence and amount of contamination, reinforcing the idea that particles that are too small to be seen still exist in the water. They continue to revise models and create new ones to explain their understanding. Students also review and add to their design questions to clean the water.

Lesson 3: Properties of Matter

This lesson centers on students' understanding that properties such as magnetism and solubility of matter can be used to identify unknown matter, and those properties can be useful in solving problems such as separating matter into categories for identification. They look for patterns, group the matter based on those patterns, and categorize the matter based on its properties. By using the properties of matter, students can begin to plan a design to solve the problem of separating and identifying the matter in the town water samples.

Lesson 4: Cleaning Water

This lesson centers on students investigating new properties of matter (evaporation and filtration) to gather data and evidence. They strengthen their understanding that properties of matter can be useful in solving problems such as separating a mixture into its component parts. They use this evidence to plan a design solution for identifying and removing the unwanted materials from the town water samples. Students define criteria and constraints of the water problem as part of the engineering design.

Lesson 5: Separating Mixtures

This lesson centers on students using all the information they have gathered regarding the properties of matter to design a process or system to separate and identify the materials in the town water samples. Students will also evaluate their processes for success in meeting the criteria and constraints and compare their results to the results of other teams' processes. By the end of this lesson, students will be closer to understanding the anchoring phenomenon that sewage water can be processed so that it is drinkable.

Learning Sequence 3-Dimensional Progressions

SEP PROGRESSION

Asking Questions and Defining Problems

Lesson 1	Students ask questions based on observation, then ask questions that can be investigated. They begin the Class Question Board and the Design Solutions Question Board.
Lesson 2	Students continue to add and refine questions for the Class Question Board and the Design Solutions Question Board.
Lesson 3	Students continue to add and refine questions for the Class Question Board and the Design Solutions Question Board.
Lesson 4	Students continue to add and refine questions for the Class Question Board and the Design Solutions Question Board. They begin to develop solutions to the problem using their Environmental Engineering Design Plan, identifying criteria and constraints.
Lesson 5	Students continue to add and refine questions for the Class Question Board and the Design Solutions Question Board. They modify their questions based on their engineering plan and the results of their prototype.

Developing and Using Models

Lesson 1	Students develop initial models to describe the town water samples.
Lesson 2	After using indicators, students refine their town water samples models to include observable and unobservable components.

Planning and Carrying Out Investigations

Lesson 2	Student conduct an investigation of the idea that matter may exist in particles too small to be seen. Using indicators, they observe that there are “invisible” particles in the water.
Lesson 3	Students conduct an investigation to learn more about the properties of matter. They explore magnetism, weight/volume, and solubility as properties of matter. In addition, they test matter for its ability to conduct electricity.
Lesson 4	Students conduct an investigation using solubility as a property that can allow filtration to separate a mixture.
Lesson 5	Students test their prototype filtration design and compare their process with other groups to determine which best meets criteria for success.

Learning Sequence 3-Dimensional Progressions (continued)

SEP PROGRESSION (continued)

Analyzing and Interpreting Data

Lesson 2	Students analyze their observational data to determine that jars #1, #2, and #3 have “invisible” components while jar #4 does not. They look for patterns in the data from other groups.
Lesson 3	Student use scientific data to think about a design solution. They compare and contrast their ideas with other groups.
Lesson 4	Student use scientific data to think about a design solution. They compare and contrast their filtration ideas with other groups.
Lesson 5	Student test their prototypes and gather data for its re-design.

Engaging in Argument from Evidence

Lesson 2	Students use evidence to support their recommendation for treatment of water at the various schools.
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Obtaining, Evaluating, and Communicating Information

Lesson 2	Students obtain information from text and media and communicate how this information supports their claims in their presentations to the school board.
Lesson 3	Students use a Frayer Model to communicate their understanding of magnetism and solubility.

Constructing Explanations and Designing Solutions

Lesson 4	Students apply scientific ideas to their engineering design plan, which is based on their evidence about the properties of matter.
Lesson 5	Students test their prototypes that were designed on scientific ideas and evidence from prior investigations. They examine and compare multiple solutions to the problem based on how well they meet the criteria and constraints of the design solution.

DCI PROGRESSION

Lesson 1	Students define a simple design problem (how to clean contaminated water) that can be solved through the development of a process or system (a filtering system for the water) based on the idea that matter of any type can be subdivided into particles that are too small to see, but the matter still exists and can be detected by other means.
Lesson 2	Students explore matter that is too small to be seen but can be detected by other means (e.g., using indicators) by engaging in a “parts per billion” investigation.

Learning Sequence 3-Dimensional Progressions (continued)

DCI PROGRESSION (continued)

Lesson 3	Students explore measurements of a variety of properties (including magnetism and solubility) that can be used to identify materials. They learn that matter can be described and classified by its observable properties. Students discover that the amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish (mixtures and solutions).
Lesson 4	Students define criteria and constraints of the town water samples problem (that matter can be too small to be seen but still exist) to design a process using the engineering design core idea. The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions are compared on the basis of how well each one meets the specific criteria for success or how well each takes the constraints into account.
Lesson 5	Students learn that possible solutions to a problem are limited due to available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. Students test different solutions in order to determine which of them best solves the problem within the criteria and constraints. At every stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

CCC PROGRESSION

Scale, Proportion, and Quantity

Lesson 1	Students consider scale as they explore that matter is made of particles too small to be seen.
Lesson 2	Students consider scale as they explore that matter is made of particles too small to be seen. They consider proportion and quantity as they investigate parts per billion.
Lesson 3	Students explore the idea that standards units are used to measure weight and volume.
Lesson 4	Students apply scale, proportion, and quantity to their criteria and constraints lists.

Patterns

Lesson 2	Students look for patterns using indicators and refine their models based on new information.
Lesson 3	Given many different types of matter, students share and discuss similarities and differences in patterns that can be used to sort and communicate information about matter.
Lesson 4	Students use patterns to begin to design solutions.
Lesson 5	Students identify patterns in successful prototypes.

Learning Sequence 3-Dimensional Progressions (continued)

CCC PROGRESSION (continued)

Cause and Effect

Lesson 2 Students learn about cause and effect in understanding parts per billion.

Energy and Matter

Lesson 2 The entire learning sequence is about the idea that matter is made of particles. Students confirm this with data obtained through indicator tests.

Systems and System Models

Lesson 5 Students develop their solution by designing a system that is composed of parts (e.g., separation by magnetism, filtration, and evaporation).

References

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. DOI: <https://doi.org/10.17226/13165>. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K–12 Science Education Standards. National Academies Press, Washington, DC.

Grade 5 What's in Your Water? Conceptual Flow

Anchoring Phenomenon

Sewage water is consumed by people, but they do not get sick.

Matter can be subdivided into particles too small to be seen, but it still exists.

Identified Problem

Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water.

PS1.A

Water is a substance that may contain particles of other matter that are dissolved in it.

PS1.A

Matter can be identified and grouped by its properties.

PS1.A

Magnetism is a property that can help identify matter. Solubility is a property of matter in which a substance dissolves in liquid. Not all matter is soluble in water.

PS1.A

Filtration is the process of separating particles from a fluid using a filter.

Evaporation is the process by which a liquid vaporizes.

PS1.A

Mixtures can be separated by physical processes based on the properties of its components.

ETS1.A, ETS1.B

ETS1.A, ETS1.B

Asking questions and defining problems

Developing and using models

Constructing explanations and designing solutions

Analyzing and interpreting data

Planning and carrying out investigations

Obtaining, evaluating, and communicating information

Obtaining, evaluating, and communicating information

Engaging in argument from evidence

Scale, Proportion, and Quantity

Patterns

Cause and Effect

System and System Models

Energy and Matter



Image via iStock.com/p_zzz



Anchoring Phenomenon

Sewage water is consumed by people, but they do not get sick.



Lesson Concept

Ask questions based on observation, then identify questions that can be investigated to identify the **matter** in the town water samples.



Identified Problem

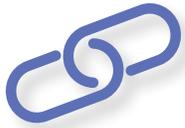
Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water.



Standards

Refer to Appendix 5.1 for NGSS, CCSS–ELA and Math, and California ELD standards.

5.1 Town Water Samples



Storyline Link

This learning sequence targets engineering design; the design challenge is to design a process that will identify the particles in the water and clean the town's water supply.

This lesson is the first in the sequence and is designed to activate students' prior experience with contaminated water, elicit their questions about contamination from observations of a video and actual water samples, and generate investigation questions that will drive their learning through the next set of lessons. This lesson introduces the identified problem: Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water. In order to do this, students, throughout the learning sequence, will build on their prior knowledge that matter is made of particles too small to be seen, but even so, the matter can be detected by other means.

In Lesson 2: Finding Impurities in Water, students will investigate how the quantity of matter in the water impacts its contamination level.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students' level of understanding and making sense of phenomena.



Time

110 minutes

Part I	20 minutes	Engage
Part II	45 minutes	Engage
Part III	45 minutes	Engage



Materials

Whole Class

- Chart paper
- Sink or tap water (warm)
- Distilled water
- 4 one-quart clear jars with lids
- 3 tablespoons sugar
- 1 tablespoon iron filings
- 4 tablespoons salt
- 2 tablespoons sand
- Long-handled spoon or stirring rod
- A small amount of sugar, iron filings, salt, and sand for display
- Drinking Filtered Sewage Water video
(<https://www.youtube.com/watch?v=sQBfCh-vmsw&feature=youtu.be>)

5.1 Town Water Samples

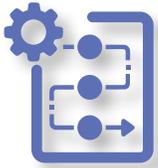
Individual

- Science notebook
- Sticky notes
- 2 different-colored pencils
- 5.1.H1: Town Water Samples

Advance Preparation

1. Prepare the four Town Water Sample jars by placing the ingredients into each jar and then filling the jar with very warm water.
 - Jar #1 has 3 tablespoons of sugar and 1 tablespoon of iron filings; stir until the sugar dissolves.
 - Jar #2 has 2 tablespoons of salt, 2 tablespoons of iron filings, and 2 tablespoons of sand; stir until the salt dissolves.
 - Jar #3 has 2 tablespoons of salt; stir until the salt dissolves.
 - Jar #4 is filled only with DISTILLED water.
2. Make copies of **5.1.H1: Town Water Samples**.
3. Preview the [Drinking Filtered Sewage Water](https://www.youtube.com/watch?v=sQBfCh-vmsw&feature=youtu.be) video (<https://www.youtube.com/watch?v=sQBfCh-vmsw&feature=youtu.be>).
4. For guidance on student-led discussions, see “The Inquiry Project’s Talk Science Primer” by Sarah Michaels and Cathy O’Connor: (https://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf).

5.1 Town Water Samples



Procedure

TEACHER NOTE

This entire lesson is an Engage, designed to elicit students' prior knowledge, gather their wonderings about contaminated water, and encourage them to think about questions they would like to investigate. Student ideas should be recorded, but not challenged or corrected during this lesson.

Part I

Engage (20 minutes)

Ask questions that can be investigated to identify the types and quantity of matter, including very small and unseen matter in the town water samples.

1. Show the [Drinking Filtered Sewage Water](#) video. Have the students think-pair-share regarding questions the video caused them to have. As a class, start a Class Question Board by recording questions raised during the discussion on sticky notes. *Expected student responses (ESRs): Who would drink that water? How could they clean it that fast? How did they know it was clean? What was in the water?*

TEACHER NOTE

For guidance on creating question boards, see Jordine, Jeff and Ruben Torres: "Enhancing Science Kits with the Driving Question Board" *Science and Children* April/May 2013; pages 57–61.

2. Ask students to help you categorize the questions. Move the sticky note questions into the new categories and tell students they will be adding to this board throughout the lesson.
3. Connect to student experiences by asking them to respond to the following prompt in their science notebook: "Think of a time when you wondered if some water was safe to drink. What made you have concerns?" Give students 3 minutes to write in their science notebook. Walk around and encourage students to expand on their writing.

TEACHER NOTE

For reluctant writers, suggest students draw a picture of their experience/memory. If a student seems stuck, ask if they would drink water from a puddle outside the classroom, a lake, or a stream. Is the water safe to drink? Why or why not?

5.1 Town Water Samples

4. Ask students to share their response with their table group and then have a representative from several groups share with the whole class. *Expected Student Responses (ESRs): I don't want to get sick; I might get a stomachache; it could rot my teeth; my mom would be really mad.* Make a summary statement of their comments: it seems like no one wants to drink "gunky" water because no one wants to get sick.
5. Have students think about the local water supply chain: "Where does the local water come from? How might the local water become contaminated? How can we prevent that from happening? How can we fix it? How can we make sure we don't have contaminated water?" Ask students to write their ideas in their science notebook and then share with a partner. Ask a few partners to share. Share this prompt: I wonder if we can think about how we could make sure we don't have contaminated water?
6. Explain to the students that they get some answers to those questions in this learning sequence, but they will not be dealing with sewage like they saw in the video.

Part II

Engage (45 minutes)

Develop a model to identify the types and quantity of matter, including very small and unseen matter, in the town water samples.

7. Introduce the problem: "There is a town that is concerned about its local water sources. Many believe that the sources have been contaminated. The town has hired you and your fellow environmental engineers to design a solution to remove the contaminants from the water. Before you can begin to design a solution to this problem, you must first ask questions about the situation that you can investigate, determine what contaminants, if any, are in the water, and learn the properties of the contaminants. Then you can determine ways in which to remove the contaminants."
8. Show the four Town Water Samples you prepared, and explain that these samples contain water collected from local sources. Pass the jars around or allow students to walk past the jars and examine them closely. To pique student interest, you can pour water from each jar into different glasses while the students observe the contaminated water. Give students an opportunity to discuss their observations in small groups.
Safety Note: Do not allow anyone to drink from the jars.
9. Ask students to work in table groups. Distribute **5.1.H1: Town Water Samples** and have the groups decide who will observe which jar (#1, #2, or #3). It is ok if some students have the same jar as long as each jar is observed by at least one person at the table. All students will observe Jar #4. Ask them to observe the contents of the jar and create a model of what they observe for their jars.

TEACHER NOTE

The students will return to **5.1.H1: Town Water Samples** in Step 12 where they will revise their models after they gather additional information.

5.1 Town Water Samples

10. Have table groups share their models. Then direct students to create a page in their science notebook titled "Town Water Samples Observations and Wonderings." Have students write questions they have concerning the contents of the jars they selected both in their science notebook and on sticky notes (one question per sticky note).
11. Have students place their sticky notes on a new page of the Class Question Board (from Step 1) in the existing categories. If necessary, make new categories for the new questions.

TEACHER NOTE

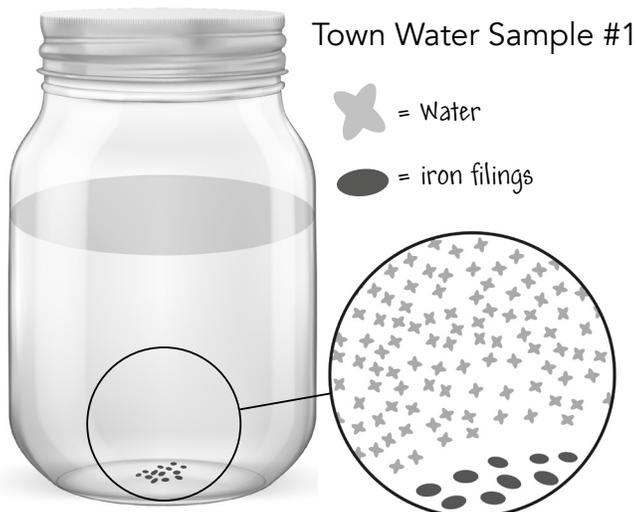
If students need scaffolding on asking questions, ask them what observations will reveal more information. You want to lead students to ask questions that can be investigated.

There are many types of questions students can ask. This lesson focuses on investigation questions rather than testable questions. The term *investigation* is the broadest category of inquiry; an *experiment* is a special kind of investigation in which variables are identified and tested to determine cause-and-effect relationships. Investigation questions are often answered by reading, research, or making observations.

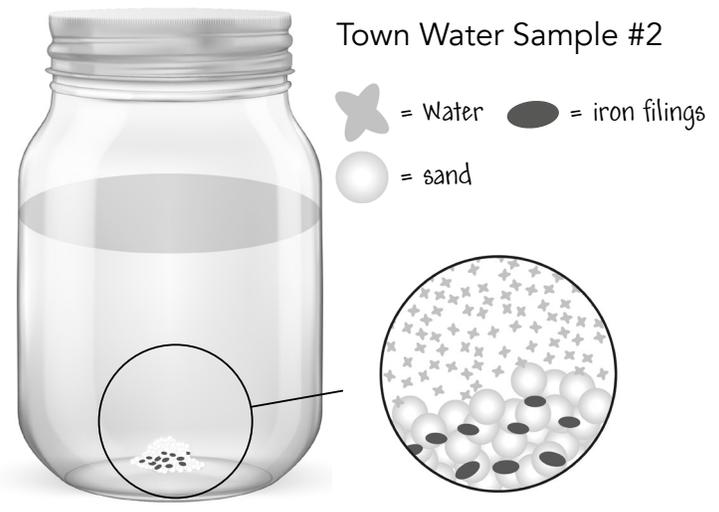
Students may generate testable questions in this lesson (e.g., *what is the effect of the contaminant on the cloudiness of the water?*). In Step 13, student will sort out these questions to be addressed at another time.

12. Make an announcement: "The police have surveyed the area where they think the contamination might have occurred. They found empty bags of sugar, salt, iron filings, and sand near the town's water sources. This could be evidence of tampering with the water." Ask students how this announcement might affect their observations and models. Have students add to or refine their models using a different-colored pencil.

Here are examples of what students might draw:

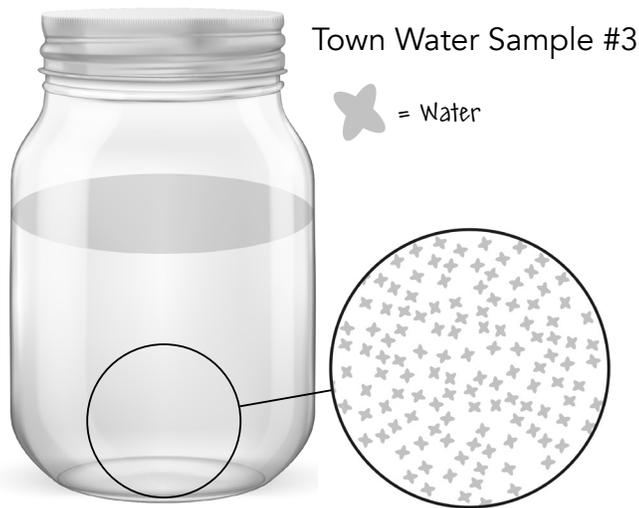


I only see water and iron filings. There could be salt and/or sugar, but I do not know for sure. They are too small to be seen.

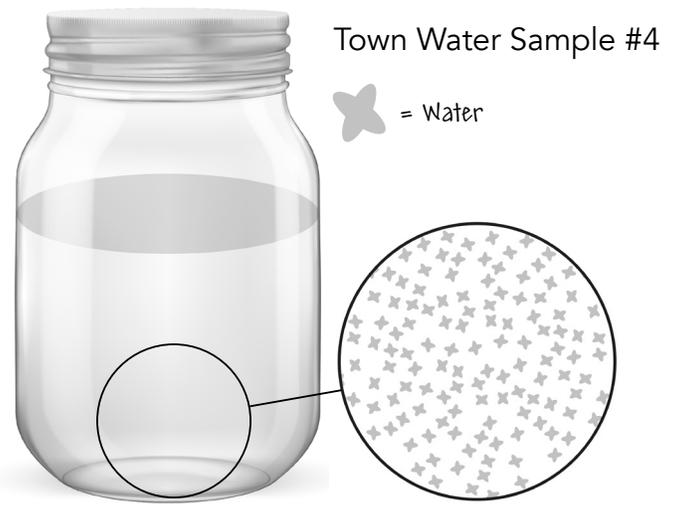


I see sand, iron filings, and water. There could also be sugar and salt in jar #2, but I do not know for sure. They are too small to be seen.

5.1 Town Water Samples



I only see water. Salt and sugar might be in jar #3, but I do not know for sure. I think they are too small to be seen.



I only see water. There could be sugar and/or salt in jar #4, but I do not know for sure. They could be too small to be seen.

13. After students have recorded their observations and developed their models, ask them to share their ideas with their table group.

- What do you notice in the different models?
- What do some of the models have in common?
- How are the parts of the model that are observable represented?
- How are the parts of the model that are not observable represented?
- Which jars have sugar or salt in them? Why do you think that? Do you know for sure?
ESRs: They could be in any of the jars, but we can't see them; a jar could have both or only one—we don't know for sure.
- Use your model to explain how there may be other material in the water that you cannot see. (See ESRs above.)
- What are you wondering about? What questions, if any, do you want to add to the Class Question Board?

TEACHER NOTE

If there were no questions about the “unseen” particles in the first set of wonderings, their refined model should now have some representation of the unknown matter in the water such as what the contaminants are, how much is present, etc. Students should now have questions about those particles.

If students are still having trouble thinking about unseen matter in the water, demonstrate for the group. Take a glass of water, add a small amount of salt or sugar, and stir until dissolved. Ask, “Can you see the salt/sugar in the water? How would anyone know it is there?”

5.1 Town Water Samples

TEACHER NOTE

► After the lesson, collect **5.1.H1: Town Water Samples** as a formative assessment to gather information to direct future lessons and provide students with feedback on the expectations for drawing a model. Assess students' application of PS1.A to see if they can use prior knowledge about the particulate nature of matter. If a student model does not include "other" particles such as sugar, salt, iron, etc. for at least jars #1, #2, and #3, remind them of the story and the samples of these materials they looked at.

Part III

Engage (45 minutes)

Ask questions that can be investigated to identify the types and quantity of matter, including the very small and unseen matter.

14. Ask table groups to share 1–2 new wonderings (questions) after they listened to the information from the police and add the questions to the Class Question Board. Ask the groups to add their sticky note questions to the appropriate categories. Create a new category if necessary.
15. Review the Class Question Board with the class, then ask table groups to select their top three questions that they think are the best investigation questions. Use these prompts to help students identify the investigation questions:
 - What questions can be answered using data from investigations?
 - What type of question would result in learning new information about the potentially dirty water?
 - Which questions are focused?
 - How might we investigate the question? (Do we have the resources in our classroom to do that?)
 - If your question is a yes/no question, how can you change it so that it asks for information (data)?

ESRs:

- *How much matter (quantity) causes the water to look dirty?*
 - *How do we know if the jar water is harmful to drink?*
 - *Are there germs in the water?*
 - *Why does the "dirt" not cause the water to smell bad?*
 - *How can the water be cleaned?*
 - *How can we determine what is in the water?*
 - *How could the environment or humans have impacted the water?*
16. At this point, move testable questions that require an experiment to another chart labeled Testable Questions.

5.1 Town Water Samples

17. Ask table groups to share their top three questions by circling them on the Class Question Board. Put check marks next to the questions that are duplicates.
18. Connect the students' questions to what they will investigate in the upcoming lessons:
 - Quantity of matter in the water (Lesson 2: Finding Impurities in Water)
 - *How do we know if the water is clean and safe to drink?*
 - *How much matter is in the water?*
 - *Is any amount of contaminating matter safe?*
 - Type of matter in the water (Lesson 3: Properties of Matter)
 - *How do we know what type of matter is in the jars?*
 - *Do any jars have no contamination?*
 - *How do we know if there is other matter in the jar?*
 - Cleaning the water (Lesson 4: Cleaning Water and Lesson 5: Separating Mixtures)
 - *How can the contaminating matter be removed from the water?*
 - *How can we make the water clean or safe to drink?*
 - *Are there different ways to clean the water?*

TEACHER NOTE

This learning sequence specifically targets the problem of material in the water and the process of removing it. Students may have questions about preventing the contamination of water. If so, create that category for the Class Question Board. If students do not yet have these questions, it is likely that they will over the course of the sequence, and the category can be added at that time. Water protection and preservation are not addressed explicitly in this learning sequence, but these questions help students realize problems that may exist within the larger system. These issues within the system can be added as an extension or differentiation strategy at the end of the learning sequence.

19. Remind students that the focus is to understand the anchoring phenomenon of sewage water becoming drinkable. We are just beginning to think about the science in the anchoring phenomenon by asking questions. We also need to think about the engineering challenge of how to clean the town water. Ask, "Which of our questions do we think we need to answer to help us explain how sewage water might be made drinkable?"
20. Have students work in pairs to review and discuss the questions in their science notebook as well as the questions on the Class Question Board. Hold a class discussion to gather the questions the students think could help in the design process. Transfer the sticky notes or rewrite them on a new question board called the Design Solutions Question Board. *ESRs: How do we know if the water is clean and safe to drink? How much matter is in the water? Is any amount of contaminating matter safe? How can the water be cleaned?*

5.1 Town Water Samples

21. Ask the class to review these questions and determine if they have any others they want to add. Have them write the questions on a sticky note and put them on the Design Solutions Question Board. Tell students they will return to this board when they are ready to think about their design.

References

60 minutes. (2018, April 29). *Drink filtered sewage water*. Retrieved from <https://www.youtube.com/watch?v=sQBfCh-vmsw&feature=youtu.be>

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Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). *Helping students make sense of the world using next generation science and engineering practices*. Arlington, VA: NSTA Press, National Science Teachers Association.

Toolbox 5.1

Town Water Samples

Toolbox Table of Contents

5.1.H1 Town Water Samples

5.1.12

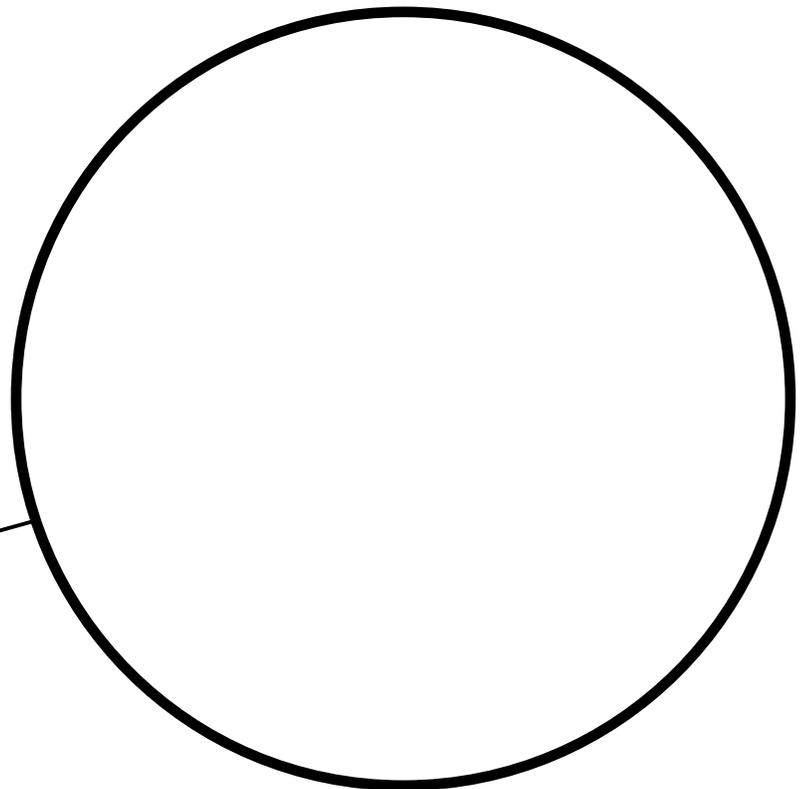
Town Water Samples

Each table group will decide who will draw each jar (#1, #2, or #3). Draw and describe a model of everything inside your jar from the perspective of two different scales:

1. as you see it (macroscopic view) and
2. as you would see it if you could shrink down to a very small scale (as you might see with a microscope)

True Scale (as seen with eye—macroscopic)

Small Scale (microscopic)



Town Water Sample # _____

Use your model to explain why you can't see the contaminants.

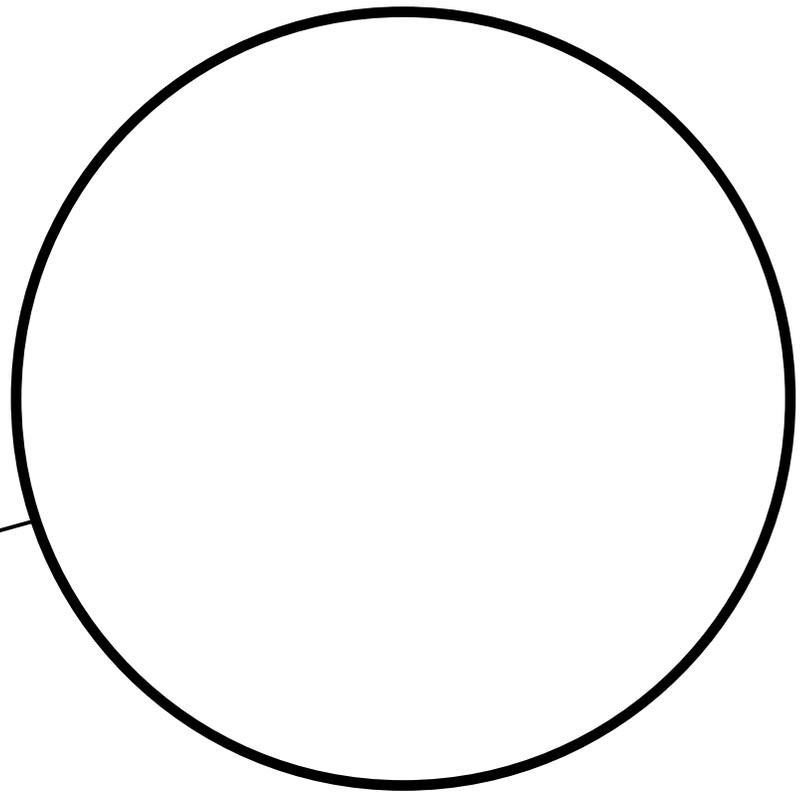
Town Water Samples (continued)

Draw and describe a model of everything inside your jar #4 from the perspective of two different scales:

3. as you see it (macroscopic view) and
4. as you would see it if you could shrink down to a very small scale (as you might see with a microscope)

True Scale (as seen with eye—macroscopic)

Small Scale (microscopic)



Town Water Sample #4

Use your model to explain why you can't see the contaminants.

Appendix 5.1

Town Water Samples

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)

- | | |
|----------------|---|
| 5-PS1-3 | Make observations and measurements to identify materials based on their properties. <i>[Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.]</i>
<i>[Assessment Boundary: Assessment does not include density or distinguishing mass and weight.]</i> |
|----------------|---|

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)

Asking Questions and Defining Problems (Target SEP)

- Use questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
- Use prior knowledge to describe problems that can be solved.
- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes criteria for success and constraints on materials, time, or cost.

Developing and Using Models (Supporting SEP)

- Develop and/or use models to describe and/or predict phenomena.

DISCIPLINARY CORE IDEAS (DCI)

PS1.A: Structure and Properties of Matter

- 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.

CROSCUTTING CONCEPTS (CCC)

Scale, Proportion, and Quantity

- Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.

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Appendix 5.1

Common Core State Standards (CCSS)

CCSS ELA SPEAKING AND LISTENING

CCSS.ELA-LITERACY.SL.5.1

Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

- b. Follow agreed-upon rules for discussions and carry out assigned roles.
- c. Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.
- d. Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

MATHEMATICS PRACTICES

MP.2

Reason abstractly and quantitatively.

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California English Language Development (ELD) Standards

CA ELD

Part 1.5.1 Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics.

EMERGING	EXPANDING	BRIDGING
Contribute to conversations and express ideas by asking and answering <i>yes-no</i> and <i>wh-</i> questions and responding using short phrases.	Contribute to class, group, and partner discussions, including sustained dialogue, by following turn-taking rules, asking relevant questions, affirming others, and adding relevant information.	Contribute to class, group, and partner discussions, including sustained dialogue, by following turn-taking rules, asking relevant questions, affirming others, adding relevant information, building on responses, and providing useful feedback.

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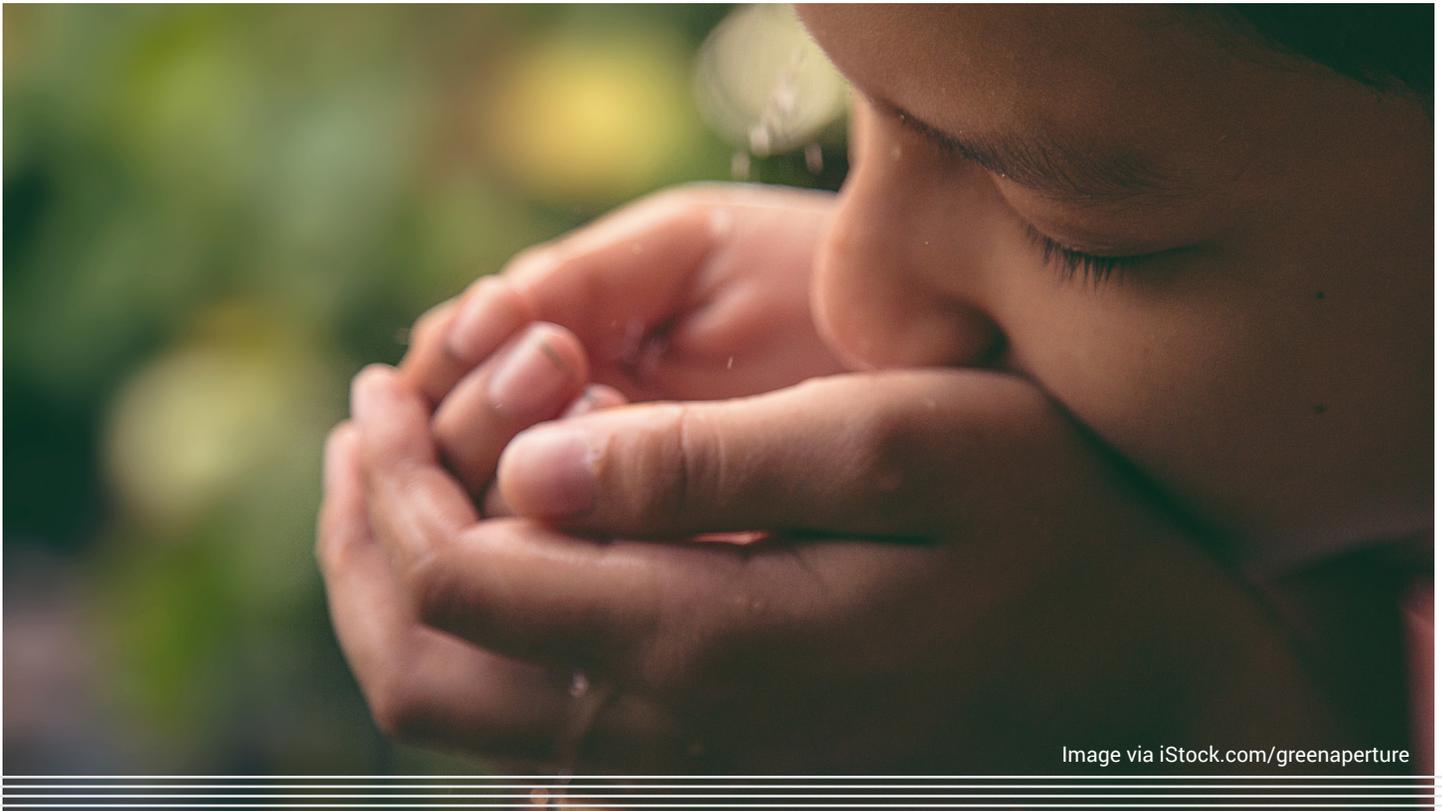


Image via iStock.com/greenaperture



Anchoring Phenomenon

Sewage water is consumed by people, but they do not get sick.



Lesson Concept

Develop and use models and recognize patterns to describe the materials that are in the Town Water Samples.



Identified Problem

Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water.



Standards

Refer to Appendix 5.2 for NGSS, CCSS–ELA and Math, and California ELD standards.

5.2 Finding Impurities in Water



Storyline Link

In the previous lesson, students were introduced to the problem that the town water might be contaminated. Students created a model of possible contaminated water and created questions to help them understand more about the contamination and to generate an engineering design to fix the contamination.

In this lesson, students use their investigation questions to identify the presence and amount of contamination, reinforcing the idea that particles that are too small to be seen exist in the water. They continue to revise their models and create new ones to explain their understanding. Students also review and add to their design questions about ways to clean the water.

In the next lesson, students explore their investigative questions about the properties of the material. This will assist them in designing their plans for cleaning the town water.

TEACHER NOTE

There are multiple models used in this lesson. To help keep track of them, this is a list of how they are used. During:

Step 1: Review their table group models of the Town Water Samples from Lesson 1.

Step 4: Create an initial model of cups A and B.

Step 9: Revise the models of cups A and B to include unseen particles identified with the indicator.

Step 14: Revise table group models of the town sample jars showing unobservable particles in jars #1, #2, and #3 but **not** #4.

Step 26: Investigate parts per billion (ppb) and develop new models on the worksheet showing parts per billion.

Step 27: Revise table group models of the town sample jars now showing parts per billion.

Step 30: Assess students' development and use of models for understanding parts per billion.

Step 32: Develop models for their evidence in board presentation.



Time

4 hours 5 minutes

Part I	20 minutes	Engage
Part II	30 minutes	Explore 1
Part III	30 minutes	Explore 2
Part IV	25 minutes	Explore 3
Part V	50 minutes	Explain
Part VI	60 minutes	Elaborate
Part VII	30 minutes	Evaluate

5.2 Finding Impurities in Water



Materials

Whole Class

- Town Water Samples (from Lesson 1: Town Water Samples)—see Advance Preparation
- Chart paper
- 2 clear water glasses (Step 4 in Advance Preparation)
- 'A Tragedy' video (<https://www.nbcbayarea.com/news/local/a-tragedy-hundreds-of-thousands-of-california-residents-exposed-to-contaminated-water/43932/>)

For classroom demo

- Distilled water (see Advance Preparation)
- 2 large clear glasses
- $\frac{1}{8}$ cup phenolphthalein (see options in Advance Preparation Step 5)
- $\frac{1}{8}$ cup bleach (see options in Advance Preparation Step 5)
- 2 eyedroppers
- How to Make Orange Juice from Concentrate video (<https://www.youtube.com/watch?v=00D6gxbeAtA&feature=youtu.be>) (Optional)

Groups of 4 (Explain)

- 1 eyedropper or plastic pipette (1 or 3 mL)
- Tap water
- 10 mL plastic graduated cylinder
- 5 2-oz. condiment clear plastic cups (or something similar)
- Masking tape or blue painter's tape
- Marking pen
- Blue or red food coloring
- Whiteboard
- Whiteboard markers

Individual

- Science notebook
- Writing tool
- Sticky notes
- 5.2.H1: Analyze This
- 5.2.H2: How Much is One Part per Billion?
- 5.1.H1: Town Water Samples (return student copies from Lesson 1: Town Water Samples with your comments)

5.2 Finding Impurities in Water



Advance Preparation

1. Review the 'A Tragedy' video. Key the video up to play from 2:08–3:08 (<https://www.nbcbayarea.com/news/local/a-tragedy-hundreds-of-thousands-of-california-residents-exposed-to-contaminated-water/43932/>)
2. Review the [How to Make Orange Juice from Concentrate](https://www.youtube.com/watch?v=0OD6gxbeAtA&feature=youtu.be) video (<https://www.youtube.com/watch?v=0OD6gxbeAtA&feature=youtu.be>) (Optional)
3. For each student, print one copy of:
5.2.H1: Analyze This
5.2.H2: How Much is One Part per Billion?

TEACHER NOTE

If local water district data and reports are available for your location, you could substitute local data for **5.2.H1: Analyze This**. Another option would be to invite a guest speaker from your local water district to present the data to your students.

4. Prepare a tray for each group containing the following items: 1 eyedropper; 5 small condiment containers; a 10 mL plastic graduated cylinder; about 10 cm of masking tape or blue painter's tape; 1 marker; a cup of water; and 1 container of dark food coloring (or have the food coloring in one location that groups can access).
5. Get ready for the classroom demonstration in Explore by filling the glasses halfway with water. Use distilled water because tap water may be basic and will turn pink in phenolphthalein.

Add 1 tsp. bleach to one glass and test with 3 drops of phenolphthalein. If the water does not turn bright pink, discard and redo with more bleach. Once it turns bright pink, discard and set up again with the appropriate amount of bleach. Label a glass of tap water without bleach A and a glass of tap water with bleach B.

TEACHER NOTE

If bleach and phenolphthalein are not available, you can substitute using the materials in this table.

Ingredient	Cup A	Cup B
Vinegar + Bromothymol blue	Water = blue	Water + Vinegar = green/yellow
Bleach + Cabbage juice	Water = red/purple	Water + Bleach = green

6. Based on which materials you are using for Explore 1, add one tsp. bleach (or vinegar) to Town Water Sample jars # 1, #2, and #3, but *not* to jar #4.

5.2 Finding Impurities in Water



Procedure

Part I

Engage (20 minutes)

Communicate information and identify patterns in the materials that are in the Town Water Samples.

1. As a table group, ask students to review their models of the Town Water Samples from Lesson 1. Ask them to discuss which samples they would be willing to drink and why. Conduct a class discussion about their reasoning. *ESRs: I would not drink from jar #1 because it has black things in it (iron filings); I would not drink from jar #2 because it has sand in it; not sure about #3 and #4—we know from our models that there could be things in there that we can't see.*
2. Ask students to think about how they could find out if jar #3 and #4 are contaminated. Have students record ideas in their science notebook, then discuss ideas with their table group or a partner. Ask students to write any new questions they have concerning the Town Water Samples. Share questions with the class and explain why or why not the questions should be added to the Design Solutions Question Board.
3. Review the Design Solutions Question Board categories from Lesson 1. Remind students that their questions are driving the lessons with the goal to develop a plan to help the town clean the water in the sample jars. Read several of the questions listed in the category related to determining how much matter is in the jar water. For example: *How do we know if the water is clean and safe to drink? How much matter is in the water? Is any amount of contaminating matter safe to drink?*

Part II

Explore 1 (30 minutes)

Conduct an investigation using an indicator (cause and effect), to determine if there are contaminants in the water.

4. ► Show the two glasses of water, one marked A and one marked B, that you prepared in the Advance Preparation. Ask student pairs to use what they know about making models to draw in their science notebook a model of what they see in the two glasses. As students draw their models, look for them to depict these ideas:
 - a single shape that represents a water particle
 - particles loosely drawn in the glass to represent a liquid
 - parts labeled

5.2 Finding Impurities in Water

TEACHER NOTE

Differentiation strategy

Based on the scaffolding needs of the students, you may need to provide a template for the model which includes the glasses already drawn and a checklist of the items to be included on the model (shown in the bulleted list above).

5. Explain that scientists use *indicators* to help identify things they cannot see, and give the definition of *indicator*: a substance used to visually show (often by the change of color) the presence of a particular material in a solution. Remind students that in their models, they drew unobservable particles. Indicators can help them confirm if those particles are really there.

TEACHER NOTE

Glass A will remain clear while glass B will turn bright pink. If vinegar and bromothymol blue are used, the glass A will turn blue and glass B will turn green/yellow. If bleach and cabbage juice are used, the glass A will be red/purple and glass B will be green.

6. Ask two students to come to the front of the classroom to participate in a demonstration. Have one student carefully add 3 drops of phenolphthalein into glass A. Explain that the drops that were added are an indicator. Ask the class, "What do you notice?" *ESR: Nothing; the water looks the same as before. We still don't know if anything is there.*
7. Then ask the other student to carefully add 3 drops of phenolphthalein into glass B. Explain that the drops that were added are an indicator. Ask the class, "What do you notice?" *ESR: The water turns bright pink. It is not the same as glass A, so something we can't see must be in there.*
8. Ask students to enter their ideas in their science notebook, writing cause-and-effect statements. You can provide this sentence frame:

The liquid in glass ____ turned ____ (effect) when the indicator was added because ____ while the liquid in glass ____ did not change because ____.

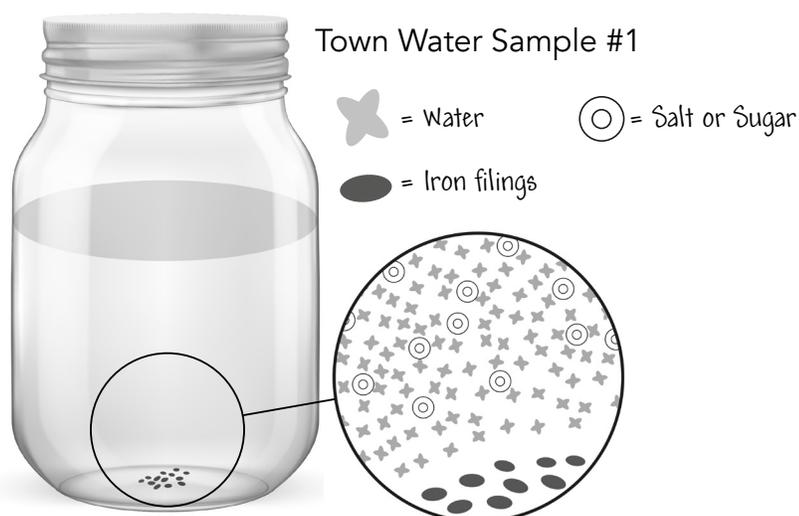
TEACHER NOTE

Cause-and-effect events have causes that generate observable patterns and can be used to explain change. It is important for students to consider this crosscutting concept to help them formulate questions that can be investigated.

5.2 Finding Impurities in Water

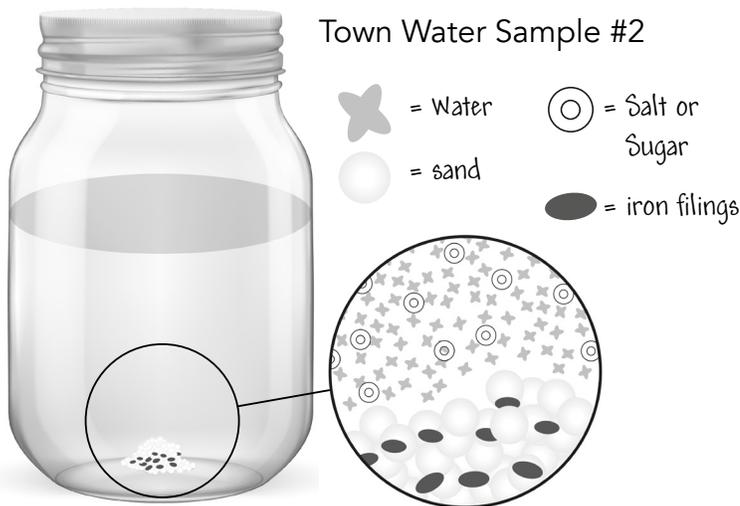
9. Ask students to review their initial model of the two glasses (Step 4) and modify their models to reflect the fact that there is a difference between the matter in the two glasses, which is why the water in the glasses looks different. If necessary, suggest the use of color and/or shapes to represent different types of particles (water particles, sand particles, etc.) in the models.
10. Have students share their revised model in pairs and discuss any new questions they might have. Then facilitate a student-led class discussion about the differences between the two glasses of water and questions the students have that could be investigated to help them identify the matter in the glasses. Write those questions on the Class Question Board. They will be referred to in Lesson 3: Properties of Matter.
11. Ask students what they might do to see if there are any unobservable contaminants in the Town Water Samples. *ESR: We could use an indicator.*
12. Have two students help with a demonstration for the whole class. One student will carefully add 3 drops of phenolphthalein into jars #1 and #2. Ask the class, "What do you notice?" *ESR: The water turned pink, meaning there is something in jar #1 besides the black things and something in jar #2 besides the sand.*
13. Ask the other student to carefully add 3 drops of phenolphthalein into jars #3 and #4. Ask the class, "What do you notice?" *ESR: The water turned pink in jar #3, but not in jar #4. There are contaminants in jar #3, but probably not in jar #4. Ask the class to identify what the contaminants might be. ESR: Perhaps sugar or salt. It could be both or only one; we don't know for sure.*
14. Ask students, based on this new information, to revise their models from Lesson 1; Town Water Samples (Step 1 in this lesson) and share with their table group.

Student models might look like this:

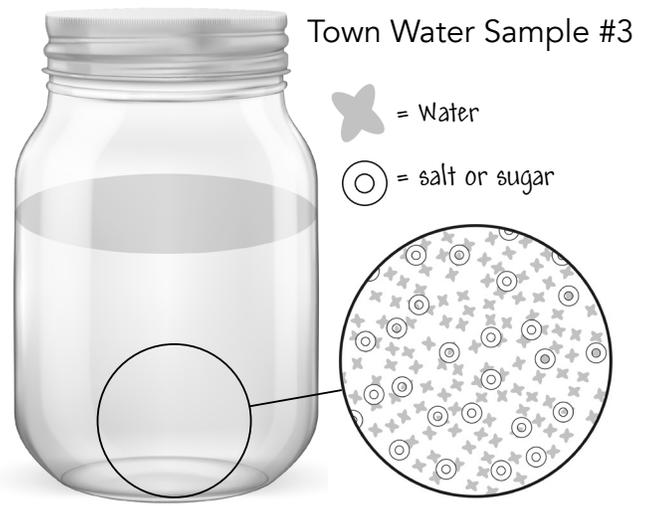


Because of the indicator, I know there are particles too small to be seen. But I do know if it is salt and/or sugar.

5.2 Finding Impurities in Water



Because of the indicator, I know there are particles in jar #2 that are too small to be seen. They could be salt and/or sugar.



Because of the indicator, I know that either salt or sugar or both are in jar #3.

Part III

Explore 2 (30 minutes)

Obtain information from media about the cause and effect of contaminants in the water.

15. We have just seen how an indicator can tell us if there is invisible matter in water. What kinds of things might be contaminating the water? (If this question is already on the Class Question Board, point to it as a reference.)
16. Play the 'A Tragedy' video from 2:06 to 3:08, which is a news clip on contaminated water. Ask students to think of questions they might ask.

TEACHER NOTE

The video segment from 2:25–2:35 describes possible causes of contamination; segment 2:45–2:51 lists some contaminants; segment 2:51–3:00 describes possible health impacts.

If it's necessary to provide greater student engagement, find a news clip or news article on water contamination for a local area with which students are familiar.

17. At the end of the video clip, ask students to talk with their table groups using these prompts:
 - "What are you thinking about after viewing this video?"
 - "What would a model of this water look like? How is the same or different than the models you have been developing?"
 - "Does watching this clip change your thinking about what's in jar #3 or #4?"

5.2 Finding Impurities in Water

18. Ask a couple of table groups to share their ideas. *ESRs: The model of this water would look like the models we have been developing showing observable and non-observable features. We would use different shapes for each of the particles. Our particles would include water and contaminants. Our models would be labeled. All the jars except #4 could have contaminants.*
19. Next, ask table groups to focus on these two questions:
 - “What experiences have you had related to poor water quality?”
 - “How might water contamination affect California (or your location) on a large scale?”
20. Distribute sticky notes to the groups. Provide the prompt: “As a result of the video and your discussion, what new questions does your group have about the Town Water Samples?” Write one question on each sticky note.
21. Ask groups to select 2–3 questions to share with the class. Facilitate a student-driven class conversation about students’ questions. Record new student-generated questions on the Class Question Board or the Design Solutions Question Board in the correct category. Check marks can be used to indicate questions that are repeated.

Part IV

Explore 3 (25 minutes)

Obtain information about the scale, proportion, and quantity of the materials that are in the water.

22. Ask, “How much stuff is in the water? Where do you think we can find answers to this question?” Facilitate a student-driven conversation about ideas on how answers to this question can be found. Chart responses on paper. *ESRs: Conducting investigations in class, sending samples to experts for testing, looking to published materials related to the topic, talking to experts, doing research at a water treatment plant.*

TEACHER NOTE

The idea of using published materials leads to the Explain of this lesson. If this suggestion does not come up, guide the discussion to the idea.

23. Using the student-generated ideas of asking experts or using published materials on possible water contamination to find answers to their questions, provide students with a copy of **5.2.H1: Analyze This**. Read it together as a class. Direct students to underline the evidence in the article that suggests that matter that is too small to be seen can be detected by other means.

5.2 Finding Impurities in Water

TEACHER NOTE

The readability level is 6.2. Students should read or follow along as the article is read aloud.

Differentiation strategy

Struggling readers can be provided more direct instruction on finding evidence as the article is read aloud to them. A discussion of key vocabulary and phrases to look for that suggest “matter is too small to be seen” can occur prior to reading; for example: cannot be seen, no color difference, no taste.

Example evidence:

Paragraph 1: Lead-tainted water has no unusual color, odor, or taste but can damage nerves in the body.

Paragraph 3: While lead in water can't be seen or smelled, there are tests to detect it.

Alternatively, if local water district data and reports are available for your location, substitute local data for **5.2.H1: Analyze This** in order to elicit greater student interest. Another option would be to invite a water district guest speaker to present the data to your students.

Part V

Explain (50 minutes)

Analyze and interpret data to develop a model that indicates the scale, proportion, and quantity of the materials in the water.

24. After reading **5.2.H1: Analyze This** bring the class's attention to the quantity *15 parts per billion* which appears in the third paragraph. Have students discuss with a partner what they think *parts per billion* means and if they can think of a real-world example of one part of something per billion total parts. Use examples from the Teacher Note below to prompt their thinking. Ask students to identify the two materials that are compared in the article (amount of lead is compared to the amount of water).

TEACHER NOTE

Parts per billion (ppb) means there is one unit of a contaminant in one billion total units. Parts per billion indicate the mass of matter in a unit volume of water. Real-world examples of one part per billion (ppb) include:

One grain of sand on the beach

One blade of grass on a football field

One second in nearly 32 years

5.2 Finding Impurities in Water

TEACHER NOTE (continued)

One penny in 10 million dollars

One foot on a trip to the moon

One drop of water in an Olympic-size swimming pool

One sheet in a roll of toilet paper stretching from New York to London.

Differentiation strategy and/or math lesson connection

Write out the number 15

Then underneath it write the number 1,000,000,000
and address place value.

ELA connection

There are several picture books that can be used to help students understand the concept of very large numbers. These include:

- *A Million Dots* by Andrew Clements (2006)
- *Millions, Billions, and Trillions: Understanding Big Numbers* by David A. Adler (2014)
- *How Much Is a Million?* by David M. Schwartz (1985)

25. Connect the reading with the next demonstration of how contaminants can become invisible in the water. Ask students they have ever diluted anything—what was their experience? For example, have they ever made orange juice from a can? What did they do to make the orange juice from the concentrate? *ESR: We had to keep adding water until the concentrate was diluted.* What do they think would happen if they continued to add water? Would it look the same? Would the color get lighter or darker? Would the taste stay the same?

TEACHER NOTE

If students have never made orange juice from a concentrate, play the [How to Make Orange Juice from Concentrate](#) video.

26. Connect making the orange juice from concentrate to how students can investigate the dilution of matter (contaminants) in water. Students will start with a visible quantity and use dilutions to illustrate that matter can be present even when it is no longer visible to our eye. Distribute **5.2.H2: How Much is One Part per Billion?** Have students work in groups of 4 to follow the directions and answer the questions.

5.2 Finding Impurities in Water

TEACHER NOTE

Students may not be familiar with using eyedroppers and/or graduated cylinders for measuring volume. Demonstrate the proper use of an eyedropper/pipette. The tip is pointed towards but not in the water container, and the bulb is squeezed and then lowered into the water. Once in the water, the bulb is released, and water is drawn into the eyedropper. Without exerting pressure on the bulb, the eyedropper is lifted out of the water and held tip down into the graduated cylinder. Gentle pressure is used to squeeze the bulb so that a drop forms at the tip and is pulled out by gravity.

For more information on using a pipette, watch the first 40 seconds of [Using a dropping pipette](#). But note that this video only demonstrates how to get fluid into the pipette and not how to use it to make drops. To make drops, you must use controlled, slight pressure on the filled eyedropper/pipette.

The graduated cylinder is used to measure (quantify) liquid volume. If students have not used a graduated cylinder before, demonstrate proper reading of the volume in the graduated cylinder by reading the bottom of the meniscus, or curve, of the water.

27. After the groups have completed their dilutions, have them share their results with two other groups, comparing and contrasting their models.
28. Remind students that they have revised their model from Lesson 1 regarding the 4 jars based on the indicators. They now know about parts per billion. Ask pairs to discuss how this information can be added to their model. Then ask students to revise their model.
29. Then as a class, discuss how their ideas may affect the problem of the Town Water Samples.

Part VI

Elaborate (60 minutes)

Evaluate and communicate information and argue from evidence (data and models) about patterns in the particles in the water.

30. Scientists often have to present data and models to make a case for an engineering design to solve a problem. Have students review the data charts at the end **5.2.H1: Analyze This**. Tell students, “The Portland Public Schools board of education is concerned about contaminated water and what to do about it. You will have an opportunity to present your findings and recommendations to the school board. You will use your models and the data in **5.2.H1: Analyze This**.”
31. ► Have students return to **5.2.H1: Analyze This** and review the data for School B only. To assess students on their understanding of scale, proportion, and quantity, ask students to use a whiteboard or a piece of chart paper to draw one particle model of a glass of water coming from the drinking fountain at school B for room 215 and another particle model for the drinking fountain at school B by the door of room 200. Tell students this model does not need to be accurate (they do not need to draw a billion dots), but it should indicate their understanding of the differences by showing room 215 fountain has 2 parts in the same volume that room 200 has in 24 parts (or 1 part for room 215 to 12 parts for room 200).

5.2 Finding Impurities in Water

32. Now have students work with a partner to analyze and interpret all of the school graphs. The following prompts can be provided to guide student analysis of the data:
- Is the water clean at these schools? (Is there other matter in the water?) How do you know?
 - Should students be drinking from the water fountains at school A? B? C?
 - Which school A, B, or C would you prefer to attend if you wanted water from drinking fountains? Why?

TEACHER NOTE

For more information about Talk Science and the discussion types, visit:

https://inquiryproject.terc.edu/shared/pd/TalkScience_Primer.pdf

<https://inquiryproject.terc.edu/shared/pd/cc/DiscussionTypes.pdf>

33. ► Ask partners to make a poster (or whiteboard) presentation for the Portland Public Schools board of education detailing the availability of safe drinking water at one of 3 specific school sites. Ask students to choose one of these three claims to support; do not include the information in parentheses as this is for your information:
- School A has the highest levels of drinking water contamination. (highest level of contamination, the greatest number of fountains exceeding the limit)
 - School B has the safest drinking water available. (lowest level of contamination (below the limit) for fountains)
 - School C has the highest number of safe drinking water fountains available. (greatest number of fountains below the limit, but those below the limit are in the range of 5–10 ppb, the one fountain exceeding the limit is the lowest compared to the other school sites)

Student presentations must state:

- the claim they are addressing (choice a, b, or c),
 - the evidence from the data that supports their claims,
 - models of their evidence, and
 - possible concerns that students still have regarding the drinking water at that specific school site.
34. After student pairs have completed their posters, do a gallery walk. Provide students with sticky notes to record feedback on the posters. Facilitate the gallery walk and peer feedback.

5.2 Finding Impurities in Water

TEACHER NOTE

Gallery walks and peer feedback suggestions are available in several resources, including: http://www.assessmentforlearning.edu.au/professional_learning/peer_feedback/peer_strategies_enhance.html.

Students should engage in constructive critiques and comments when providing feedback.

If possible, provide students with sample critiques that cite specific evidence which supports a claim and specific “wonderings” for any concerns.

35. After the gallery walk, ask students to discuss with their partners any additional ideas they now have after comparing their work to that of other groups. Give students an opportunity to revise their work.

Part VII

Evaluate (30 minutes)

Communicate information about the particles of matter (energy and matter) and apply it to the engineering design.

36. Ask students to write in their science notebook at least two things they learned about models in this lesson. For example, over time, how did their beginning model change? *ESRs: I learned that models help me “see” what is going on; models can get more refined with new information such as ppb; my models from Lesson 1 of the water samples now shows unseen particles in all jars.*
37. Ask students to write in their science notebook at least two things they learned about what might be in the water. *ESRs: I learned that bad things like lead can be in the water without being visible and that lead can hurt me; I learned that contamination is measured by parts per billion and even if we don’t think it is there, it is; I learned to use data and our models to make a presentation.*
38. Ask students to share their ideas from both prompts with their table group. Ask the table group to pick three ideas that they think will help them in their design and two or three questions they now have.

TEACHER NOTE

This is an opportunity for brainstorming and creative thinking by students to reflect on the difficulty of quantifying extremely small values. It also provides an opportunity to formatively assess student understanding of ppb. All answers are acceptable.

39. Have tables share their ideas and questions and add to the Design Solutions Question Board. Conduct a discussion on what students are thinking based on their understanding of parts per billion.

5.2 Finding Impurities in Water

40. Look for a question on the Class Question Board or on the Design Solutions Question Board that is similar to “If there is stuff in the water, what is it?” If that question is not there, prompt students with: “Now that you know a clear glass of water can still be contaminated, how could a scientist investigate the types of matter in the Town Water Sample jars in order to determine all the contents in each jar? Be sure to consider the steps and requirements that scientists need to address in order to make sure the results are reliable.”
41. Conduct a brief discussion and chart some of their ideas to use in Lesson 3: Properties of Matter. The lesson will focus on identifying unique and quantifiable properties of matter in order to identify matter.

TEACHER NOTE

This prompt leads to the Lesson 3: Properties of Matter on identifying unique and quantifiable properties of matter in order to identify matter which is the next question to be addressed on the Design Solutions Question Board.

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Toolbox Table of Contents

5.2.H1	<u>Analyze This: Real data on lead levels in school drinking water</u>	5.2.17
5.2.H2	<u>How Much is One Part in a Billion?</u>	5.2.20

Analyze This: Real data on lead levels in school drinking water

Monitoring for lead (as in these data) is an important part of identifying risks to health.

by Lillian Steenblik Hwang



Water that appears clear and clean can be unsafe if it contains high amounts of lead, a toxic metal.

Image via [iStock.com/Joseph Thomas Photography](https://www.iStock.com/JosephThomasPhotography)

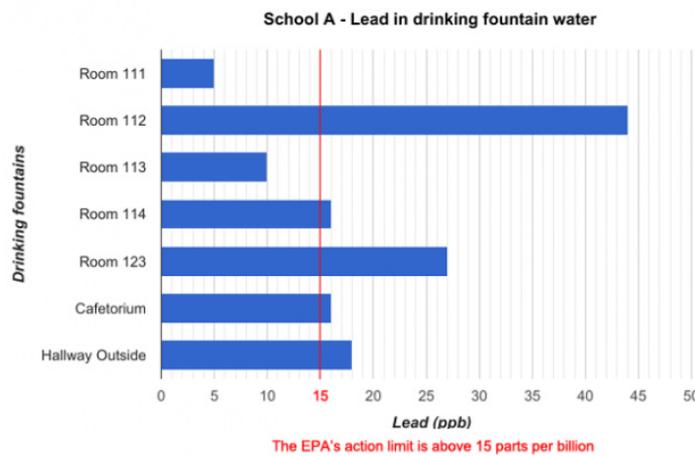
You turn on the faucet to get a glass of water. The liquid comes out clear and odorless. It's safe, right? Maybe not. In some places, such as Flint, Michigan, water coming out of the tap may contain lead, a toxic heavy metal. Finding it can be hard because lead-tainted water has no unusual color, odor or taste. But once inside the body, that lead can damage nerves—including those in your brain!

There are many ways that lead can enter drinking water. The most common way is from the pipes that connect a home or school to a town's main water-supply lines. In many cities, there are still lots of old pipes made of lead. Lead also can be found in the material used to seal connections between pipes. (That sealant has been banned but may still exist in some pipes.) The metal in many faucets, fountains and water outlets also may contain lead.

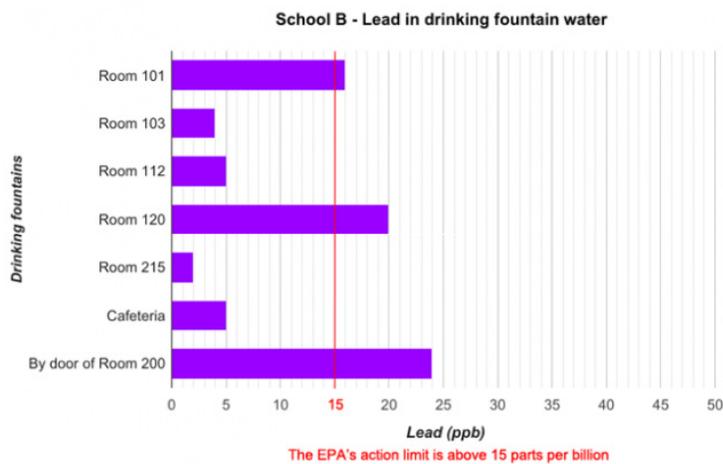
The best way to avoid lead poisoning is to avoid exposure. While lead in water can't be seen or smelled, there are tests to detect it. If those tests reveal that the water has a lead level higher than 15 parts per billion (ppb), the U.S. Environmental Protection Agency (EPA) recommends that people take action to reduce the contaminant. But even low levels are not safe—just safer.

Analyze This: Real data on lead levels in school drinking water (continued)

School districts around the country regularly test their water for lead. Last year, for instance, Portland Public Schools in Oregon had all of their buildings tested. Preliminary data from these tests are [now available online](#). Some of the data from three schools are graphed below. The data graphed include six or seven locations from each of three Portland schools. The school district tested nearly 100 buildings.

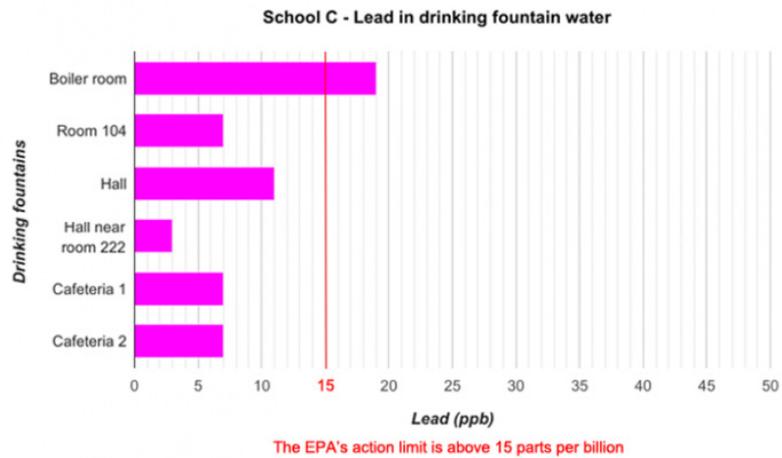


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Analyze This: Real data on lead levels in school drinking water (continued)



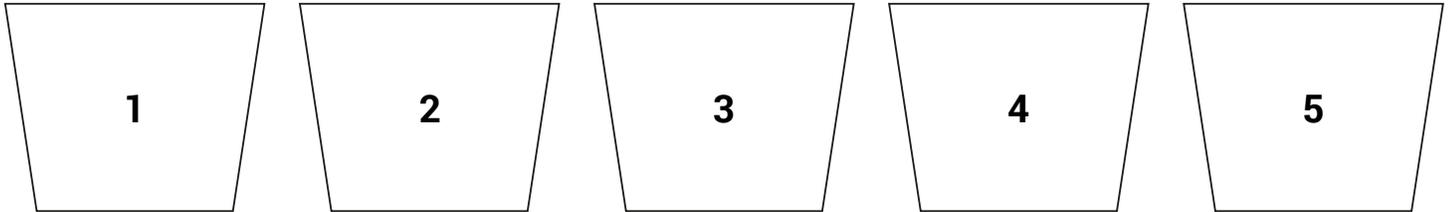
L. Steenblik Hwang

Lillian Steenblik Hwang, Science News for Students, May 3, 2011. Used with permission.

How Much is One Part in a Billion?

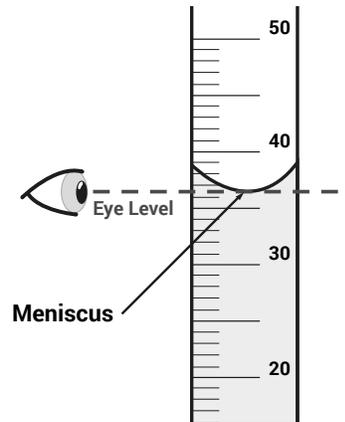
Procedures:

Label the 5 cups with numbers 1, 2, 3, 4, and 5 as shown below.



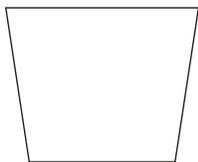
Working with Cup 1

- a. Using the eyedropper, place 99 drops of water in the graduated cylinder. Read the volume of the amount of water and record the volume below. Remember to read volume at the bottom of the meniscus (curve of the water). (See the image to the right.)



The volume of 99 drops of water is ____ mL.

- b. Pour the 99 drops of water into cup 1.
c. Add one drop of food coloring dye to cup 1. Stir.
d. Draw a particle representation of cup 1 below. This represents one part per hundred or 1/100.



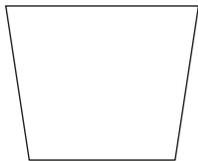
Cup 1

1 drop of dye + ____ drops of water = 1 part in 100 total parts.

How Much is One Part in a Billion? (continued)

Working with Cup 2

- a. Measure another 99 drops of water by pouring it to the same mark on the graduated cylinder as you did for cup 1.
- b. Transfer this water into cup 2.
- c. Take one drop of water from cup 1 and add it to cup 2. Stir.
- d. Draw a particle representation of cup 2 below.
This represents one part in ten thousand ($1/10,000$ or $1/100$ divided by 100).

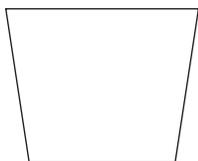


Cup 2

1 drop from cup 1 + ____ drops of water = 1 part in 10,000 total parts.

Working with Cup 3

- a. Measure another 99 drops of water by pouring it to the same mark on the graduated cylinder.
- b. Transfer this water into cup 3.
- c. Take one drop of water from cup 2 and add it to cup 3. Stir.
- d. Draw a particle representation of cup 3 below.
This represents one part in one million ($1/1,000,000$ or $1/10,000$ divided by 100).



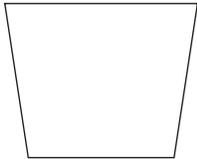
Cup 3

1 drop from cup 2 + ____ drops of water = 1 part in 1,000,000 total parts.

How Much is One Part in a Billion? (continued)

Working with Cup 4

- a. Measure another 99 drops of water by pouring it to the same mark on the graduated cylinder.
- b. Transfer this water into cup 4.
- c. Take one drop of water from cup 3 and add it to cup 4. Stir.
- d. Draw a particle representation of cup 4 below.
This represents one part in one-hundred million ($1/100,000,000$ or $1/1,000,000$ divided by 100).

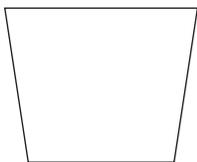


Cup 4

1 drop from cup 3 + ____ drops of water = 1 part in 100,000,000 total parts.

Use Cups 4 and 5 to Make 1 Part Per Billion

- a. To make one part per billion, place 9 drops of water in cup 5.
- b. Take one drop from cup 4 and add it to cup 5. Stir.
- c. Draw a particle representation of cup 5 below.
This represents one part in one billion ($1,000,000,000$ or $1/100,000,000$ divided by 10).



Cup 5

1 drop from cup 4 + ____ drops of water = 1 part in 1,000,000,000 total parts.

Compare and contrast your cup results and model representations with two other groups. Discuss with the other groups and then answer the following questions.

How Much is One Part in a Billion? (continued)

1. Our group results are similar to _____ because _____

2. Our group results are different from _____ because _____

3. What are some reasons for similarities and differences in data?

Appendix 5.2

Finding Impurities in Water

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
5-PS1-1	Develop a model to describe that matter is made of particles too small to be seen. <i>[Clarification Statement: Examples of evidence supporting a model could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water, and evaporating salt water.] [Assessment Boundary: Assessment does not include the atomic-scale mechanism of evaporation and condensation or defining the unseen particles.]</i>

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Planning and Carrying Out Investigations
<ul style="list-style-type: none">Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.Make observations and/or measurements to produce data to serve as the basis for evidence an explanation of a phenomenon or test a design solution.
Developing and Using Models
<ul style="list-style-type: none">Identify limitations of models.Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regularly occurring events.
Analyzing and Interpreting Data
<ul style="list-style-type: none">Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
Engaging in Argument from Evidence
<ul style="list-style-type: none">Compare and refine arguments based on an evaluation of the evidence presented.Construct and/or support an argument with evidence, data, and/or a model.Respectfully provide and receive critiques from peers about a proposed procedure explanation, or model by citing relevant evidence and posing special questions.Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.
Obtaining, Evaluating, and Communicating Information (Supporting SEP)
<ul style="list-style-type: none">Read and comprehend grade-appropriate complex text and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.

Appendix 5.2

DISCIPLINARY CORE IDEAS (DCI)**PS1.A: Structure and Properties of Matter**

- 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.

CROSSCUTTING CONCEPTS (CCC)**Patterns**

- Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products.

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change.

Scale, Proportion, and Quantity

- Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

Energy and Matter

- Matter is made of particles.

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Common Core State Standards (CCSS)

CCSS ELA READING**CCSS.ELA-LITERACY.RI.4.7**

Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs) and explain how the information contributes to an understanding of the text in which it appears.

CCSS ELA SPEAKING AND LISTENING**CCSS.ELA-LITERACY.RI.5.7**

Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.

CCSS.ELA-LITERACY.SL.5.1

Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

- Follow agreed-upon rules for discussions and carry out assigned roles.
- Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.
- Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

Appendix 5.2

MATHEMATICS PRACTICES

MP.2

Reason abstractly and quantitatively.

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California English Language Development (ELD) Standards

CA ELD

Part I.5.6a Reading/viewing closely

EMERGING	EXPANDING	BRIDGING
a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with substantial support.	a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with moderate support.	a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade level texts and viewing of multimedia with light support.

In addition to the standard above, you may find that you touch on the following standard as well:

P1.5.1 Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics.

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Image via iStock.com/harmpeti



Anchoring Phenomenon

Sewage water is consumed by people, but they do not get sick.



Lesson Concept

Make observations and measurements to identify patterns of materials by their properties.



Identified Problem

Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water.



Standards

Refer to Appendix 5.3 for NGSS, CCSS–ELA, and California ELD standards.

5.3 Properties of Matter



Storyline Link

In the last lesson, students used their investigation questions to identify the presence and amount of contamination, reinforcing the idea that particles that are too small to be seen still exist in the water. They continued to revise models and create new ones to explain their understanding. Students also reviewed and added to their design questions about how to clean the water. The next question they will explore is “How can the properties of matter help us know what is in the water?”

This lesson centers on students’ understanding that properties such as magnetism and solubility of matter can be used to identify unknown matter, and those properties can be useful in solving problems such as separating matter into categories for identification. By using the properties of matter, students can begin to plan a design to solve the problem of separating and identifying the matter in the Town Water Samples.

In the next lesson, students will create a plan to separate substances using the properties of magnetism or a substance’s ability to dissolve into water.

Throughout the lesson, a flag (▶) denotes formative assessment opportunities where you may change instruction in response to students’ level of understanding and making sense of phenomena.



Time

4 hours 15 minutes

Part I 2 hours 30 minutes

- 45 minutes Engage
- 60 minutes Explore 1
- 45 minutes Explain 1

Part II 1 hour 45 minutes

- 60 minutes Explore 2
- 30 minutes Explain 2
- 15 minutes Elaborate/Evaluate



Materials

Whole Class

- Town Water Samples (from Lesson 1: Town Water Samples)
- Chart paper
- Markers
- 4 small kitchen digital scales
- 1 box of cereal fortified with iron
- 2-inch magnet
- 1 sandwich zipper bag

5.3 Properties of Matter

Group (Groups of 4)

- Large whiteboard (or chart paper) and markers
- Steel ball bearing (size of a marble)
- Glass marble
- Rubber ball (about 2 inches in diameter)
- Pom-pom (½-inch or less in diameter)
- Small pebble
- Aluminum foil (2-inch square)
- Magnet
- Small paper clip
- Iron nail
- Steel nail
- Mirror (approximately 2-inch square or round)
- 1-inch washer
- Magnetite (available on the internet)
- For making a circuit to test for conduction of electricity:
 - D cell battery
 - Battery holder
 - Light bulb
 - Bulb holder
 - Three wires with alligator clips at ends
- Aluminum baking pan (9-inch x 12-inch)
- Penny
- 5.3.G1: Property Labels
- Envelope

Group (Groups of 2)

- 5 clear 8-oz. cups, each filled with ½ cup water
- 5 small 3-oz. disposable cups, one of each will contain:
 - 2 tsp. sugar
 - 2 tsp. sand
 - 2 tsp. powdered drink mix or instant tea
 - 2 tsp. baking soda
 - 2 tsp. flour

5.3 Properties of Matter

- 1 digital kitchen scale
- 5 wooden craft sticks
- 2 hand lenses

Individual

- Science notebook
- Writing tool
- 5.3.H1: Properties Table
- 5.3.H2: Frayer Model
- 5.3.H3: Exit Ticket
- 5.3.H4: Mixing Matter Observations



Advance Preparation

1. Crush all the fortified with iron cereal and put it into a bowl. Check to make sure that when a magnet is put into the crushed cereal that it collects the iron.
2. Set up 10 trays using the aluminum container with items to sort in Explore 1: steel ball bearing, glass marble, rubber ball, pom-pom, small pebble, aluminum foil, magnet, small paper clip, iron nail, steel nail, mirror, washer, and magnetite.
If you need to substitute items, see **5.3.H1: Properties Table** for information on the properties the students will use for sorting and find objects that have those properties.
3. At each table provide a whiteboard and markers for the group.
4. Print one copy of **5.3.G1: Property Labels** for each group of 4 students. Cut a set of labels and place them all in an envelope.
5. For each student, print one copy of **5.3.H1: Properties Table**, **5.3.H3: Exit Ticket**, and **5.3.H4: Mixing Matter Observations** and two copies of **5.3.H2: Frayer Model**.
6. For Explore 2, set up 5 plastic cups with water for each set of partners. Also, put one of the following into its own small disposable cup: 2 tsp. of sugar, sand, powdered drink or instant tea, baking soda, and flour. Then assemble a tray with the 5 plastic cups with water, the 5 small cups, each with one substance, 5 mixing sticks, 2 hand lenses, and 1 digital kitchen scale.

5.3 Properties of Matter

7. Make electricity testers, or if you prefer, have each group make their own. Connect one alligator clip to the battery holder and to the base of the light bulb holder. Connect another alligator clip to the other side of the battery holder. Connect a third alligator clip to the other side of the light bulb holder. Place the item you want to test between the two free ends of the clips and see if the bulb lights.

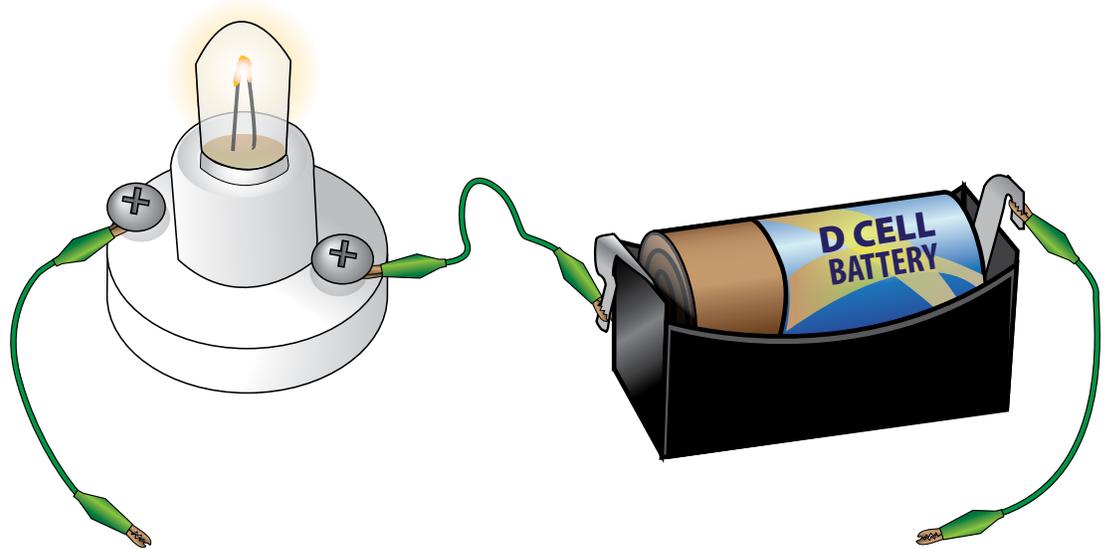


Image via WestEd [[CC BY-NC-SA 4.0](#)]

5.3 Properties of Matter



Procedure

Part I

Engage (45 minutes)

Analyze and interpret data from observations and measurements of patterns that indicate the properties of matter.

TEACHER NOTE

Students will review their prior knowledge of the basic properties of matter from second grade. Then they will build on that understanding to address the 5th-grade DCI properties of elements such as magnetism, conductivity (electrical and thermal), reflectivity, solubility, and measurement to identify unknown matter.

1. Ask table groups to review their models of the Town Water Samples. Which jars contain contaminants? Which jar(s) do not? How do they know? *ESRs: jars #1, #2, and #3 are contaminated with observable and non-observable matter. We can observe the black things (iron filings) and the sand in jars #1 and #2. We know there are unobservable particles in jar #3 from the indicator test. Jar #4 does not have contaminants because it stayed clear when tested.*
2. Hold up sample jar #4 and ask students to discuss whether the water in the jar is clean or contaminated in some way that is different from the rest of the jars. To help them in their discussion, ask for other examples where they may wonder if there are very small quantities of matter in other items they consume. (*Examples may include bacteria on food, gases in air*). Ask several students to share their ideas.
3. Show students the box of cereal that is fortified with iron and ask, “How can we determine what substances might be contained in items we use every day? What do you think is in cereal fortified with iron?” Ask students to share ideas with a partner, and then reconvene as a class and record their ideas on the board or chart paper.
4. Ask, “How can we find out what is in this cereal?” *ESR: Read the ingredients.* Read the ingredients and vitamin/mineral nutrition label aloud. Ask, “Is anything on the list surprising?” Have students discuss with a partner and/or in table groups. Students are likely to be surprised that iron is on the list. (Note: Iron is a mineral added to many cereals.) If they do not ask, wonder aloud yourself why iron would be in cereal.
5. Ask: “I wonder how we can find out if there is iron in the cereal? I wonder if it is really metal or if there is some other kind of iron?” (e.g., iron dietary supplements)
6. Have students discuss with a partner their thoughts, ideas or questions as to the idea of iron in the cereal. Discuss the responses and the pros and cons of the strategies suggested. Record students’ ideas.

5.3 Properties of Matter

TEACHER NOTE

Record responses from students in three columns on your chart. Use these headings:

How to find out if there is iron in the cereal	Is it metallic iron or another form of iron?	Questions/Wonderings
--	--	----------------------

This can be referred to later in the lesson to see if students' questions were answered and if their ideas for finding out if about iron in the cereal worked.

7. Ask three students to help with a demonstration. Ask one student to show the bowl of crushed cereal to the class. Then have the student add water to make it soggy and stir. Show the bowl to the class. What do they notice?
8. Ask the second student to take the magnet and put it inside a sandwich zipper bag, removing the air. Ask the student to swirl the bag with the magnet several times in the watery cereal.
9. Ask the third student to take the bag out of the cereal and show their classmates what is on the outside of the bag. Either display it under a doc camera or have the student walk around the room.
10. Ask the students to discuss what the stuff on the outside of the bag is. *ESRs: The stuff on the outside is very small and dark. It might be iron because we know iron is in the cereal from the ingredients list.*
11. If it is iron, what property does it have that allowed us to remove it from the cereal? *ESR: The magnetic property of iron enabled us to use a magnet to separate it from the cereal.*
12. Connect this activity to the Class Question Board item that asks how we can identify what matter is in the Town Water Samples. Ask students to respond to this prompt in their science notebook: "How can what we just did with the cereal help us to determine if any iron is in each of the Town Water Samples?" Ask a couple of students to share their thinking. Conduct a classroom discussion about how the property of magnetism and the use of a magnet can be used to solve the problem of the Town Water Samples.

Explore 1 (60 minutes)

Test for properties of matter (weight, magnetism and conductivity) and analyze data to determine patterns.

13. Continue the discussion asking, "How can knowing the properties of different types of matter help us solve our problem of identifying what's in the water sample jars?" *ESRs: We know there is contamination in our samples and in the sewage water (anchoring phenomenon). Knowing different properties can help us identify what the matter is and figure out how to remove or separate it.*

5.3 Properties of Matter

14. Explain that students will now have the opportunity to explore and identify the properties of various types of matter. Before they get started, ask students how they might make observations of properties. *ESRs: We will use our senses; use tools like a magnet, or test it for electrical conductivity.*

TEACHER NOTE

If students do not mention testing for electrical conductivity, suggest it to them. Fifth-grade students should have prior experience with electrical circuits, conductors, and insulators. If they don't have this background knowledge, introduce it to them. You could hold up a tester and ask students what they know about it and then build from there.

Ask if anyone knows how to use the tester and build on the responses. If no one has knowledge of that, show students how to use the tester by placing an object between and touching the two open wires to see if the bulb lights.

15. Distribute the prepared tray of items to each group, and pose this question: "Looking at these items, what similarities and differences in their properties can be identified in order to sort and classify them?"

TEACHER NOTE

► If you ask students to write, rather than talk about their responses to the question, you can assess prior knowledge of the properties of matter that were taught in second grade. Student misconceptions regarding magnetism can also be assessed at this point.

16. Ask students to work as a team to sort the items by their properties. On a whiteboard or chart paper, ask students to make a group record showing the items that were sorted and the property used to group them.

TEACHER NOTE

Use one of these sentence frames as a discussion scaffold if needed:

One property that these items can be sorted/classified by is ____.

For example, the ____ can be classified as a(n) ____.

Another property that these items can be sorted by is ____.

17. Have teams review their sorting, asking them to compare and contrast their data to find patterns. Ask students to record their ideas in their science notebook.

5.3 Properties of Matter

TEACHER NOTE

► Formative assessment: Students are responding to how they sorted based on the patterns of properties. Students should include magnetism and patterns of similarities of items. *ESRs: These items are grouped together because they all are attracted to a magnet; these items are grouped together because they all conduct electricity.*

DCI Support:

Starting in second grade, students learned materials could be classified by observable properties. In third grade, students learned that magnetism is a force that causes objects to be pushed or pulled. In fifth grade, they understand how this force can be used to identify the properties of matter.

CCC Support:

In grades K–2, students developed an understanding that patterns in the natural and human-designed world can be observed. In grades 3–5, this shifts to an understanding that similarities and differences in patterns can be used to sort for designated properties.

18. Conduct a gallery walk: Each group leaves their sorted items and whiteboard display and visits another group's board. Students observe similarities and differences in the ways the different items were sorted. Guide students to look for patterns in objects that are sorted in groups. Take notice of any patterns in the way the matter was sorted focusing on the relationships of the items in each group. Ask, "How are the sorting groups of others similar to your sorting? How are they different?"
19. In table groups, discuss patterns of both differences and similarities that were noticed in the gallery walk. Have each table group share one idea.
20. Show the class a penny and ask, "Based on the sorting groups you made, what group or groups might this penny fit in?" Distribute a penny to each group to use in the next sorting.

TEACHER NOTE

► This activity can be a quick, whole-group formative assessment of the properties of matter for PS1.A (e.g.: not magnetic, conducts heat, conducts electricity, metal).

21. Distribute the envelopes containing the labels you cut from **5.3.G1: Property Labels**. Discuss and review the labels and units (such as grams, centimeters) that would likely be recorded when scientists measure the various properties. Ask, "Do all properties have units?" (no) Students work as a team to re-sort their items on the tray by the properties on the labels.

5.3 Properties of Matter

TEACHER NOTE

In the first sort (Step 15) students sorted into their own categories. In Step 21, students are asked to re-sort using the labels as categories. This may provide different categories than the students originally had thought of. It also provides academic language for the categories.

If needed, help students understand that one of the new properties, weight, will be used as they re-sort objects in the tray. When describing the term weight, do not include any discussion of mass. Instead refer to weight as the heaviness an object has compared to other objects. The purpose is to provide more concrete examples of using the CCC for Scale, Proportion, and Quantity.

Explain 1 (45 minutes)

Communicate information about the properties of matter that can be used to categorize objects.

22. Distribute **5.3.H1: Properties Table** to each student and have students record the items in the appropriate category, based on their sorting. Ask them to discuss how this sorting was different from their original sort. Then have students record in their science notebook the different ways one item can be sorted based on the item's properties.
23. ► Circulate while student teams discuss and describe how they sorted the items and their reasons for sorting the items the way they did. Based on your assessment of student discussions during the team sorts, provide feedback to the class. You might need to explain the new properties including weight (the heaviness an object has compared to other objects) and magnetism (the ability of some metal objects to be attracted to a magnetic force).
24. Distribute **5.3.H2: Frayer Model** and have students write the term magnetism in the oval. Using the general rules or characteristics discussed, have students complete the other squares.

TEACHER NOTE

A Frayer Model is completed by writing several examples and non-examples of the vocabulary term being defined.

In third grade, students learned that magnetism is a force that causes objects to be pushed or pulled. In fifth grade, they understand how this force can be used to identify properties of matter.

Differentiation strategy

Advanced students can create a Frayer Model for the term *weight* while the teacher works with students who need more guidance on *magnetism*. When describing the term *weight*, do not include any distinction between weight and mass at this grade level.

5.3 Properties of Matter

25. After completing **5.3.H2: Frayer Model**, ask the teams to discuss how magnetism may be helpful in separating matter. How are magnets used in the real world to solve problems? Record their ideas in their science notebook.

TEACHER NOTE

Magnets are used to separate metals from other trash and lift heavy objects like vehicles at a salvage yard where old vehicles are crushed. Maglev trains like a monorail use magnets. In addition to these physical science uses of magnetism, there are also life science connections to the use of magnetism. Magnetism is used by several species to help with navigation (birds and tiger sharks).

26. ► Hand out **5.3.H3: Exit Ticket**. Ask students to complete this prompt: “What properties did you use to sort the materials that were collected in your properties table?” Collect **5.3.H3: Exit Ticket**.

TEACHER NOTE

The goal of the exit ticket is to get students to communicate how specific properties can be used as a process or method to separate matter that might be in the Town Water Samples. Students are making a claim about the merit of a solution by citing evidence which they will use in the next lesson.

Review the exit slips for student understanding before beginning Explore 2 (e.g., did they relate the idea of the small particles of iron to small weight/quantity?). Adjust Explore 2 accordingly.

Part II

Explore 2 (60 minutes)

Conduct an investigation to observe the property of solubility of different materials using scale and proportion.

27. Return student’s **5.3.H3: Exit Ticket** for their review. Address any questions/concerns.
28. Share with students some interesting questions you gathered from the last question on the **5.3.H3: Exit Ticket**.
29. Show Town Water Sample jars #1, #2, and #3 again. Ask students, “How could you use the properties that we just learned about to separate the matter that is in these jars? Have students discuss with a partner, then class share.

5.3 Properties of Matter

30. Refer to the Class Question Board, finding one that relates to matter mixing with other matter. Ask students if they can think of examples of different types of matter mixing together. *ESRs: Trail mix has nuts and fruits; punch is made from mixing powder with water; chocolate syrup is added to milk to make chocolate milk.* Then ask, "What examples do you know of mixed solutions that appear clear but have something in them?" *ESRs: salt water or sugar water.* If you do not get this response, see the Teacher Note box.

TEACHER NOTE

This is the students' first exposure to the property of *solubility*. The purpose of your questions is to elicit student's background knowledge. Hopefully from the questions that students have asked, one relates to mixing. If not, ask the question: "What would be an important property of matter when making lemonade with fresh lemons? If you want your lemonade sweet, what might you do?" *ESR: Add sugar.* Ask, "What must the sugar do to make the lemonade sweet?" *ESR: Dissolve in the lemon juice.* Ask, "What does dissolve mean?" Have students discuss with a partner.

31. Explain that students will have an opportunity to explore their thinking by investigating how different matter mixes with water. Some matter mixes with water, and some matter does not. Ask students how mixing or not mixing with water or another liquid might be an important property to help solve the Town Water Sample problem. *ESR: If it mixes, it might change the water like when you put sugar in tea or lemonade to make it sweet. If it doesn't mix, then maybe it can be removed.*
32. Explain that scientists use a property called solubility to determine if one type of matter can dissolve in another type of matter. Ask partners to discuss what this means for the Town Water Samples. *ESRs: We think that in jars #1 and #2 the black things and the sand didn't dissolve. But we know from using the indicators that there are other particles we can't see in jars #1, #2, and #3. We think these particles have dissolved.*
33. Distribute the second tray to each pair. Tell them, "To explore your ideas on solubility, you have these materials to work with:
- There are five 8-oz. clear cups with $\frac{1}{2}$ cup of water in each.
 - There are 5 3-oz. small cups with 2 teaspoons of the item labeled on the cup.
 - 5 wooden sticks for stirring, one for each substance.
 - Kitchen scale for weighing the matter, before and after the mixing.
 - Hand lenses for observing each type of matter in the small cups."
34. Ask students what data would be helpful to record when mixing materials. *ESRs: which ones disappear; which ones don't mix; how much disappears; is there a color change; does the mixed matter act differently than the original two materials?*

5.3 Properties of Matter

35. Hand out and review the first two columns of **5.3.H4: Mixing Matter Observations**. Discuss what words will make helpful observations on **5.3.H4: Mixing Matter Observations**.

TEACHER NOTE

Differentiation strategy

Allow students to create their own data tables.

36. Ask students to talk to a partner about the columns on **5.3.H4: Mixing Matter Observations** that have to do with weight. Why might weight be an important property of matter? *ESRs: If the matter is heavy, it could sink to the bottom; if it's light, it might stay on top; if the matter disappears, it should weigh less.* Chart their responses (to return to after the investigation).
37. Have a discussion about weighing matter. Ask, "What are the appropriate tools? What should you keep in mind when weighing something?" Have table groups discuss and share ideas. *ESRs: need to be accurate in measuring the weight; need to use a scale with numbers; need to "center" the scale so that it starts at zero; need to make sure that you are measuring the weight of the item and not the weight of the item plus the container it is in.*
38. Build on the idea of the weight of container vs. weight of material if that is brought up by students. If not, introduce that idea. Weigh a cup with water in it and show students the value. Ask, "Is this what the water really weighs?" Allow students time to discuss, and if no one mentions the weight of the cup, then ask: "But what about the cup? Does it weigh anything? How could we find out how much the water actually weighs?" Encourage discussion and additional examples of appropriate methods for collecting data about objects' weight. It is important to ask probing questions about the standard units used for measuring and reporting weight; that is, in our everyday life, we measure weight in pounds; in our science work, we measure weight in grams.

TEACHER NOTE

The goal of Step 38 is to get students to realize that they must weigh the cup when it is empty, then subtract the weight of the cup from the weight with the matter inside the cup. When students weigh the small cups of substances, they must weigh the cup separately and subtract the weight of the cup from the weight of the cup with the substance.

To conserve time, the weight of both the cups (clear plastic and small paper) can be completed in front of the class and the data recorded on the board. Alternatively, have an extra of each cup (empty) on the trays for students to do themselves.

If students do not know how to use the scales, demonstrate for them.

5.3 Properties of Matter

39. Explain that students will use the materials on the tray to investigate different types of matter and how they interact with water. They will collect observational data to see which mix in with water and which do not. This data may be crucial in helping them solve the Town Water Sample problem.
40. Ask students to work in pairs to observe the different materials and record observations on **5.3.H4: Mixing Matter Observations**. Allow partners to decide how they will mix the matter with the water. Some may dump it all at once while other groups will be more cautious and pour it in stages. Allow all options. Circulate to hear the discussions students have about their observations as they perform the investigation.

Explain 2 (30 minutes)

Analyze and interpret data from observations and measurements of the properties of matter.

41. Put these questions on the board and have students discuss each question in their table groups using their data from **5.3.H4: Mixing Matter Observations**.
 - a. "What did you notice?" *ESR: Some matter "disappeared," some did not.*
 - b. "Did the matter really disappear? What is your evidence?" *ESRs: It looked like it disappeared, but the weight of the water and matter stayed the same, so it still had to be there.*
 - c. "Which matter dissolved in the water? What is your evidence?"
 - d. "Which did not dissolve? What is your evidence?"
 - e. "What do you think causes some matter to dissolve in water and other matter to not dissolve?" (The purpose of this question is to get students to look for a pattern that might be helpful for their designed solution and tests to separate the water and contaminants in the town samples.)

TEACHER NOTE

Students are being introduced to the new element of PS1.A: amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish. Students may think the matter "disappears" or vanishes when mixed into the water, but the weight will indicate that matter is in the water; it's just not visible. This helps students grasp the meanings of *solubility* and *dissolving*.

42. Review the student thinking from Step 38 and discuss with students how their thinking has changed about materials disappearing.
43. ► Distribute another copy of **5.3.H2: Frayer Model**, and have students write a term *dissolve* in the central oval and complete the model. Ask partners to share their ideas. Listen for how students talk about dissolving. You want them to realize that that they know it doesn't disappear, it just becomes invisible because matter is made of particles too small to be seen.

5.3 Properties of Matter

44. Assign each table group a solution to keep. (It is fine if there are duplicates as long as all solutions are represented.) Ask them to place their solution on a countertop and label the solution.

TEACHER NOTE

The retained solutions must be allowed to evaporate so that crystals or a film residue are left behind in the cups. You may wish to have them leave the wooden sticks in the cups so that the crystals and residue can be passed around on the sticks during the next lesson.

Evaporation depends on many factors and may take longer than expected. A heat lamp can be used to speed up the process. If you prefer, prepare a set of solutions and set them aside a week prior to beginning this exploration.

Elaborate/Evaluate (15 minutes)

Ask questions/define problems to determine how to identify the different materials in water samples.

45. Look on the Class Question Board for a question similar to “How can we remove the contaminating matter from the water in the jars?” In table groups, ask students to discuss this question. If necessary use prompts such as:
 - a. “How could using specific tools, or a process for separation, help identify the matter that might be in the Town Water Sample jars? “
 - b. “What tools and processes would you use to clean the water in the jars?” Note: This response leads to Lesson 4: Cleaning Water.
46. Conduct a brief class discussion using the ideas from the table groups. Ask if there are any new questions to add to the Class Question Board or if any questions can now be deleted.

Toolbox Table of Contents

5.3.G1	<u>Property Labels</u>	5.3.17
5.3.H1	<u>Properties Table</u>	5.3.18
5.3.H2	<u>Frayer Model</u>	5.3.19
5.3.H3	<u>Exit Ticket</u>	5.3.20
5.3.H4	<u>Mixing Matter Observations</u>	5.3.21

Property Labels

Cut and place cards into an envelope.

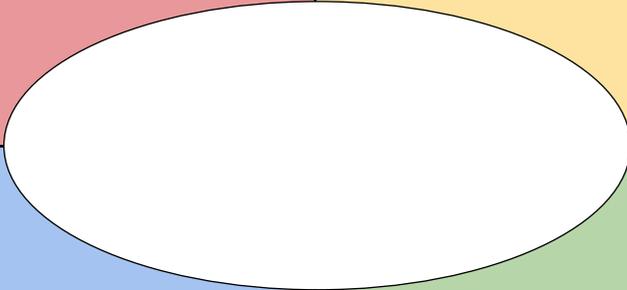
METAL	NON-METAL	WARMER THAN ROOM TEMPERATURE
CONDUCTOR	INSULATOR	WEIGHS MORE THAN A PENNY
WEIGHS LESS THAN A PENNY	MAGNETIC	NON-MAGNETIC
REFLECTIVE	COLDER THAN ROOM TEMPERATURE	NON-REFLECTIVE

Properties Table

Properties	Objects Classified
Metallic (Metal)	
Non-Metallic (Non-Metal)	
Lights the Light Bulb (Conductor)	
Does not Light the Light Bulb (Insulator)	
Magnetic	
Non-Magnetic	
Weighs less than a penny	
Weighs more than a penny	
Reflective	
Non-Reflective	
Warmer than room temperature	
Colder than room temperature	

Frayer Model

Definitions	Characteristics
Examples	Non-Examples



Exit Ticket

Name: _____

1. We made a group based on the property _____. We chose the _____ (item) because _____. We also chose _____ (item) because _____. A tool that is helpful in sorting for _____ (property) is _____ because _____.

2. The property of _____ allowed us to separate _____ from the cereal. How might this activity help us to investigate the Town Water Samples?

3. How could the property of conducting electricity help us to investigate the Town Water Samples?

4. How could the property of weight help us to investigate the town water supply?

5. Other questions I have:

Mixing Matter Observations

Directions:

1. Write the weight of the 8-oz. and 3-oz. cups from the class measurement.
2. For each substance, calculate the final weight of the substance and water by using the formulas shown below.
3. For each substance, write your observations of the substance before you add the water and then after the water has been added.

Clear 8-oz. plastic cup weight: _____ Small 3-oz. cup weight: _____

Matter	A Weight of 3-oz. cup	B Weight of cup + substance	C Weight of Substance (B-A=C)	D Weight of 8-oz. cup	E Weight of cup + water	F Weight of water (E-D=F)	G Weight of water and substance (C+F=G)
Flour							
Observations before and after mixing with water:							
Baking Soda							
Observations before and after mixing with water:							

Mixing Matter Observations (continued)

Matter	A Weight of 3-oz. cup	B Weight of cup + substance	C Weight of Substance (B-A=C)	D Weight of 8-oz. cup	E Weight of cup + water	F Weight of water (E-D=F)	G Weight of water and substance (C+F=G)
Sugar							
Observations before and after mixing with water:							
Sand							
Observations before and after mixing with water:							
Drink Mix or Tea							
Observations before and after mixing with water:							

Appendix 5.3

Properties of Matter

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
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. <i>[Clarification Statement: Examples of reactions or changes could include phase changes, dissolving, and mixing that form new substances.] [Assessment Boundary: Assessment does not include distinguishing mass and weight.]</i>
5-PS1-3	Make observations and measurements to identify materials based on their properties. <i>[Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.] [Assessment Boundary: Assessment does not include density or distinguishing mass and weight.]</i>

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Asking Questions and Defining Problems
<ul style="list-style-type: none">• Use prior knowledge to describe problems that can be solved.• Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes criteria for success and constraints on materials, time, or cost.• Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
Planning and Carrying Out Investigations
<ul style="list-style-type: none">• Evaluate appropriate methods and/or tools for collecting data.• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
Analyzing and Interpreting Data
<ul style="list-style-type: none">• Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.• Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics and/or computation.• Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.

Appendix 5.3

DISCIPLINARY CORE IDEAS (DCI)**PS1.A: Structure and Properties of Matter**

- Measurements of a variety of properties can be used to identify materials.
- The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish.

CROSSCUTTING CONCEPTS (CCC)**Scale, Proportion, and Quantity**

- Natural objects exist from the very small to the immensely large.
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

Patterns

- Similarities and differences in patterns can be used to sort and classify, communicate and analyze simple rates of change for natural phenomena and designed products.

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Common Core State Standards (CCSS)

CCSS ELA SPEAKING AND LISTENING**CCSS.ELA-LITERACY.SL.5.1**

Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

- Follow agreed-upon rules for discussions and carry out assigned roles.
- Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.
- Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

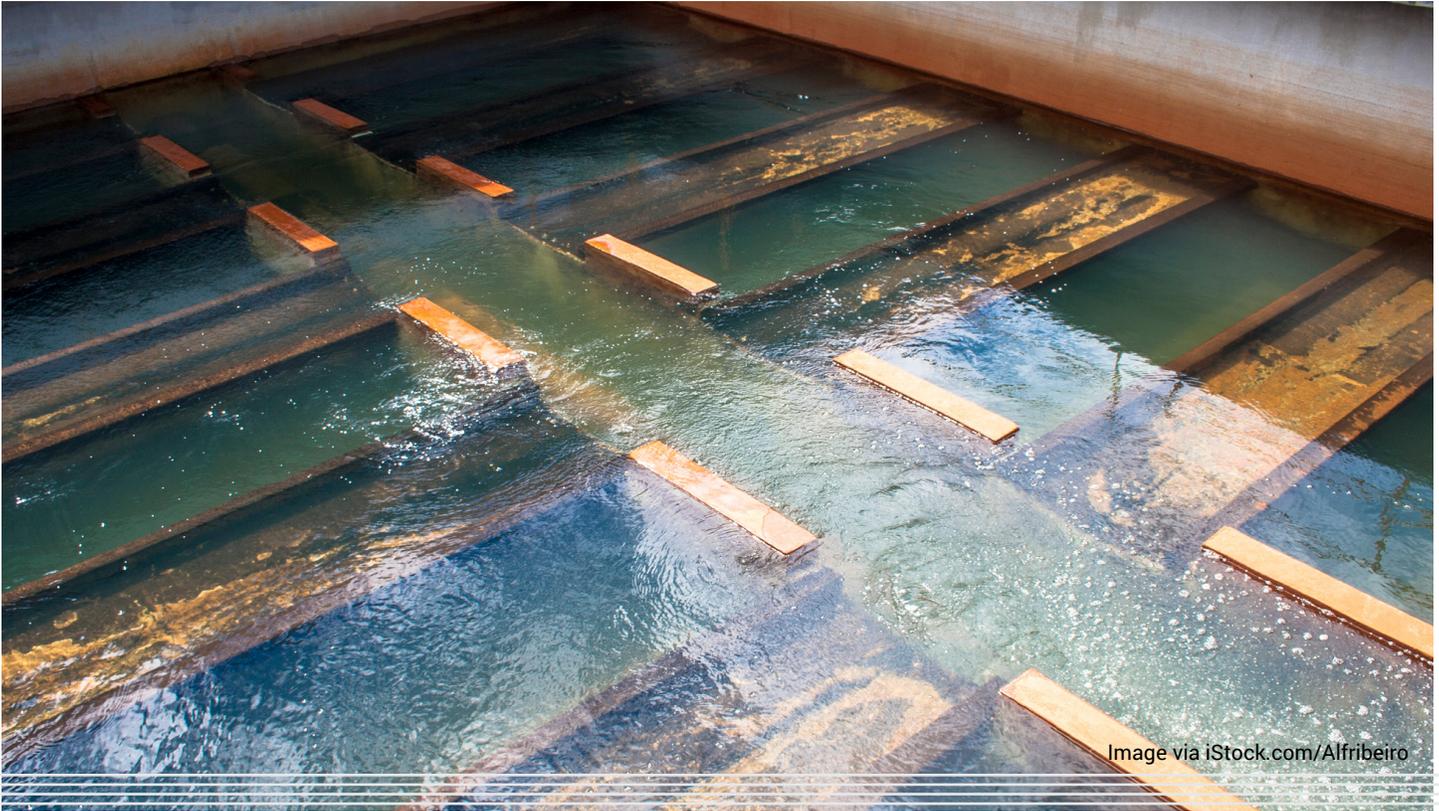
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Appendix 5.3

California English Language Development (ELD) Standards

CA ELD		
Part 1.5.6a Reading/viewing closely		
EMERGING	EXPANDING	BRIDGING
a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with substantial support.	a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with moderate support.	a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with light support.
In addition to the standard above, you may find that you touch on the following standard as well: P1.5.1 Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics.		

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Anchoring Phenomenon

Sewage water is consumed by people, but they do not get sick.



Lesson Concept

Ask questions based on observation, then identify questions that can be investigated to identify patterns in the type and quantity of matter in the town water samples.



Identified Problem

Water collected from neighboring communities may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water.



Standards

Refer to Appendix 5.4 for NGSS, CCSS ELA and Math, and California ELD standards.

5.4 Cleaning Water



Storyline Link

In the last lesson, students learned new properties of matter (magnetism, electrical conductivity, weight, and solubility) and continued to use their knowledge of matter and the various properties of matter to identify substances. These properties can also be useful in solving problems such as separating a mixture.

This lesson centers on students investigating new properties of matter (evaporation and filtration) to gather data and evidence. They use this evidence to plan a design solution for identifying and removing the unwanted materials from the town water samples. Students define criteria and constraints of the water problem as part of the engineering design.

In the next lesson, students will use their possible design solutions to identify and separate matter from the water contained in the town water samples.



Time

3 hours 50 minutes

Part I with optional explore 1 hour 25 minutes + evaporation time

- 15 minutes Engage
- 30 minutes Explore 1
- 30 minutes Optional: Explore 1a
- 10 minutes Explain 1

Part II 2 hours 25 minutes

- 60 minutes Explore 2
- 45 minutes Explain 2
- 40 minutes Elaborate/Evaluate



Materials

Whole class

- Chart paper
- Town Water Samples (from Lesson 1: Town Water Samples)
- Cups (stored at the end of Lesson 3: Properties of Matter)
- [The Engineering Design Process: A Taco Party video \(https://ca.pbslearningmedia.org/resource/tacoparty/tacoparty/#.WlwBxN-nFPY\)](https://ca.pbslearningmedia.org/resource/tacoparty/tacoparty/#.WlwBxN-nFPY) (optional)

Items for making the solution for the filtration system (add other items you might have such as sponges, other fabrics, cotton)

- 20 paper bowls
- 20 8-oz. clear plastic cups

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- 20 4-in. squares of screens
- 20 4-in. pieces of cheesecloth
- 20 small shallow plastic bowls
- 2 1-quart water containers
- 20 plastic spoons
- 20 1-inch round magnets
- 20 coffee filters
- 1 paper towel roll
- 30 hand lenses
- 12 3-oz. small cups
- 4 small digital kitchen scales
- 15 tablespoons (kitchen measuring type)

Groups (Optional activity in Explore 1) (Groups of 4)

- 4 12-oz. jars
- 2 cups water
- 6 cups granulated sugar
- 4 wooden skewers to hang in jars about an inch from the bottom
- 4 clothespins
- Food coloring

Individual

- Science notebook
- Whiteboard
- Green and yellow sticky notes
- 5.3 H4: Mixing Matter Observations (from Lesson 3: Properties of Matter)
- 5.4.H1: Separating Mixtures
- 5.4.H2: Exit Ticket
- 5.4.H3: Environmental Engineer Design Plan
- 5.4.H4: Sugar Water Assessment
- 5.4.H5: Rubric

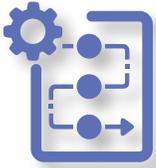
5.4 Cleaning Water



Advance Preparation

1. For each student, make a copy of **5.4.H1: Separating Mixtures**, **5.4.H2: Exit Ticket**, **5.4.H3: Environmental Engineer Design Plan**, **5.4.H4: Sugar Water Assessment**, and **5.4.H5: Rubric**.
2. For some specific strategies, explanations, and helpful ideas for doing engineering with fifth graders, review Chapter 11 of the *California Science Framework* (see references), particularly pages 1478–1484 and 1489–1490. These pages also provide explanations and specifics for the engineering design process.
3. Preview *The Engineering Design Process: A Taco Party* video (<https://ca.pbslearningmedia.org/resource/tacoparty/tacoparty/#.WlwBxN-nFPY>) to determine if you want to use it.

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Procedure

Part I

Engage (15 minutes)

Use patterns to ask questions to identify unique properties of matter.

1. Ask students to discuss with a partner this prompt: “What are some properties of matter that you investigated in our last lesson?” Ask partners to review their data from **5.3.H4: Mixing Matter Observations**, paying attention to their observations before and after adding water to each substance. What patterns did they notice? *ESRs: some mixed and stayed clear; others did not mix; some looked like they disappeared, but we know that they are still there; the particles are just too small to be seen.*
2. Show the cups saved from Lesson 3: Properties of Matter where substances were dissolved in water. Depending on how the solutions were left, there should now be crystals or film residues forming on the craft sticks left in the cups. Have students respond in their science notebook to each of these prompts:
 - a. What do you notice about the water in the cups?
 - b. How do you think these crystals and residue formed?
 - c. What are these crystals and residue?
 - d. How can these crystals and residue help us solve the problem of cleaning the contaminated water in the town water samples?
 - e. What new questions do you have?
3. After students have sufficient time to think and write in their science notebook, have them share responses with the class. Add new questions to the Design Solutions Question Board.

TEACHER NOTE

Focus on the “cleaning the water” section of the Design Solutions Question Board.

Possible Extension: Students may have questions about preventing contamination of water. If so, add that category to the Design Solutions Question Board. If students do not yet have these questions, it is likely that these sorts of questions will emerge soon, at which point the category can be added. Water protection and preservation are not addressed in this learning sequence, but it can be added as an extension or differentiation strategy at the end of the sequence; it addresses 5-ESS3-1.

5.4 Cleaning Water

Explore 1 (30 minutes)

Obtain information from a text about how the properties of matter are used to identify materials (patterns).

4. Tell students, “Today, we are going to read about some ways to separate different types of matter that are mixed together. This may be helpful in answering some of your questions and provide more ideas for separating the “stuff” in the town water samples and ultimately cleaning the sewage water. As we read, draw a star by examples of mixtures that are separated in the real world. Draw a circle around the names of the processes used to separate mixtures. Underline definitions.”
 - a. Hand out **5.4.H1: Separating Mixtures**. Read aloud or have pairs do a shared reading.
 - b. Discuss the processes of filtration and evaporation in the article and address how the new information could be helpful in developing the plan to clean the water in the jars.
5. Challenge students to identify the difference between the processes of filtration and evaporation by revisiting the definitions in the text. Come to a class consensus on the differences. Encourage students to find evidence in the reading that focuses on the properties of matter that are important in both processes and reference exactly where the information is found in the text. *ESRs: Filtration is dependent on particle size, and evaporation is dependent on the types of matter changing phases at different times. Liquid turning into a gas is the phase change important in evaporation (and distillation). Evaporation is dependent on the property of boiling point temperature.*

TEACHER NOTE

Filtration, distillation, and evaporation are addressed in the reading. At this grade level, distillation and evaporation can be lumped together for the purpose of discussion.

Students are not expected to know boiling points at this grade level, but they should be able to state that there are properties of water and sugar (or other matter) that result in the materials evaporating at different temperatures.

6. Identify and discuss which process resulted in the formation of the crystals and residue discovered in the cups from Lesson 3: Properties of Matter and examined in Step 2 of this lesson.
The expected student response is evaporation.

5.4 Cleaning Water

Explore 1a: Optional (30 minutes, plus overnight for evaporation)

Conduct an experiment of making rock candy to identify the process of evaporation.

TEACHER NOTE

If students have difficulty understanding evaporation, have students create “rock candy” to develop a connection to the process. The directions below will yield 4 rock candy sticks of the same color. You might want to ask what color students want, and then group them by color choice to make their candy. If all of the ingredients are clean, students can eat the product!

Teacher prep: Clean the glass jars thoroughly with hot water; cut wooden skewers so that they hang about 1 inch from the bottom of the jars. Find spring-loaded clothespins that are at least the length of the jar mouth.

- 1a. Ask each student to wet their wooden skewer with water and roll it in granulated sugar. This base layer gives the sugar crystals something to grab onto when they start forming.
- 2a. Ask groups of four to create their sugar syrup. Place the water in a medium-sized pan and bring it to a boil. Begin adding the sugar, 1 cup at a time, stirring after each addition. You will notice that it takes longer for the sugar to dissolve after each cup you add. Continue to stir and boil the syrup until all of the sugar has been added, and it is completely dissolved. Remove the pan from the heat.

Note if you are uncomfortable with students doing this, set up a station in the front of the classroom where you can monitor this process.
- 3a. Have students add 2–3 drops of their favorite food coloring and stir it in to ensure an even, smooth color. Then allow the sugar syrup to cool for 20 to 30 minutes.
- 4a. Ask students to rinse the prepped jars with hot water, then pour the syrup into them.
- 5a. Ask each student to use a clothespin as a horizontal holder to lower one sugared skewer into each jar until it hangs about 1-inch from the bottom. It should **not** touch the bottom of the jar.



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5.4 Cleaning Water

- 6a. Ask students to carefully place their jar in a cool place, away from harsh lights, where it can sit undisturbed. Cover the top loosely with plastic wrap or a paper towel.

TEACHER NOTE

You should start to see sugar crystals forming within 2 to 4 hours. If you see no change after 24 hours, try boiling the sugar syrup again and dissolve another cup of sugar into it. Then pour it back into the jar and insert the skewer again.

- 7a. Allow the rock candy to grow until it is the size you want. It may take several days. Don't let it grow too wide, or it might be impossible to remove from the jar.
- 8a. Note that a top layer of crystal will form. This is okay. Once the candy has reached the desired size, break up that top layer of crystal with a fork before removing the candy.
- 9.a Transfer the rock candy to an empty jar or glass (keep the clothespins to balance it) and allow it to dry for 1 to 2 hours, then enjoy or wrap in plastic wrap to save for later.

Explain 1 (10 minutes)

Communicate information about properties of matter to make predictions based on size.

7. ► Students write a response on **5.4.H2: Exit Ticket** for each of these questions:
- How does understanding properties of matter help us use filtration to identify materials?
 - How did the crystals and residue form in the cups that were left out from the last lesson?
 - Predict what would happen if a mixture of sand and water was left to evaporate.
 - Based on your learning so far, what suggestions would you give city leaders regarding the neighboring town's drinking water problem?
8. Students discuss their responses and determine if they can add any evidence or new questions to the Class Question Board. Collect the **5.4.H2: Exit Ticket**.
9. ► Provide feedback to **5.4.H2: Exit Ticket** responses and return responses to students by Step 15.

TEACHER NOTE

Share with students some response groupings such as "I notice that about one-third of the class said _____. And a few said _____." Or "I noticed that a few people said _____ (some interesting or outlandish response)." Do this for each of the questions. Find responses that stimulate interesting discussions and promote ideas for solutions to determine the materials in the town water samples.

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TEACHER NOTE

If necessary, remind the students that neighboring communities are concerned about the local water sources for the community. Many people believe that the water sources may have been contaminated because the police found empty bags of sugar, salt, iron filings, and sand near the local water sources. People are concerned that the only way to save the drinking water is to determine what is in each of the local water supplies.

For more information on engineering practices, read chapter 13 of *Helping Students Make Sense of the World Using Next Generation Science and Engineering Practices* by Christina Schwarz, Cynthia Passmore, and Brian J. Reiser.

Part II

Explore 2 (60 minutes)

Define the problem and design a solution to separate and identify materials based on their properties.

10. Remind the class that they have been hired as environmental engineers to solve a problem. Ask, "What is the problem we are trying to solve? What are some issues to consider when thinking about how to resolve the problem?" *ESRs: The water is contaminated so we have to think about how to get the contaminants out of the water. We have to make observations and use of the properties of matter to identify and quantify the matter in each water sample, and then a design for a separation process can be made.*

11. Distribute **5.4.H3: Environmental Engineer Design Plan** and have students record the problem in the box labeled #1. If needed, students can be provided with this sentence stem:

_____ needs a way to _____ so that _____.

ESR: The town needs a way to identify matter in the water so that the contaminants can be separated from the water, making the water safe for drinking.

12. Ask table groups to identify the criteria that must be met in order to successfully resolve the water problem. Ask groups to discuss what successfully solving the problem would look like. Ask groups to share ideas and then as a class, agree to the criteria that will be used to determine a solution to the problem. Ask students to record the agreed-upon criteria in the box labeled #2 on **5.4.H3: Environmental Engineer Design Plan**.

- What are some things that are important when we consider drinking water?
- Based on these important things, what would a successful process need to do if the goal was safe drinking water?

ESRs: The visible particles will be removed from the water; no crystals or residue will be left when a small sample of water is evaporated.

5.4 Cleaning Water

It is helpful to have table groups rank and order the criteria from most important to least important. This ranking can help teams make design decisions later.

TEACHER NOTE

Criteria are the specific qualities of a successfully designed solution. For example, strength, durability, reliability, and speed can all be criteria for a design. If students need a reminder, play [The Engineering Design Process: A Taco Party](#) video, which compares the engineering design process to hosting a taco party.

13. Ask table groups to determine the limitations that are present in creating a solution to this problem. Display the materials that are available for use. (See materials list.) Provide names for items if students ask but refrain from providing details on ways to use the tools.
14. Ask table groups to share ideas, and then as a whole class agree to the constraints that will be imposed on the design solution. Then have students write the constraints in the box labeled #3 on **5.4.H3: Environmental Engineer Design Plan**.

TEACHER NOTE

Constraints describe the limitations on a design, such as resources (e.g., time, materials, and funds).

You can set some of the constraints such as Internet use or whether other materials can be used besides the ones you've provided. You can impose a maximum funding limit as long as you provide material item costs so that groups are limited to purchasing materials within a fictitious budget.

Ranking the importance of the constraints can also be helpful for group discussions.

15. Students review their exit slip responses and feedback from Step 7 and discuss with their group this prompt: "Thinking about your lesson experiences, what are some ways that your group can solve this problem and use properties of matter to first separate and then identify the matter?" Have them record the scientific information they know in the box labeled #4 on **5.4.H3: Environmental Engineer Design Plan**.
16. Ask table groups to design and write a process/plan in the box labeled #5 on **5.4.H3: Environmental Engineer Design Plan**. The plan must result in a solution to the #1: problem they identified, which most closely meets #2: the criteria they established within #3: the limitations they identified using the #4: scientific information they learned in the previous lessons. Circulate and encourage groups to address how data will be collected. This data can be qualitative and/or quantitative.

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TEACHER NOTE

If necessary, review criteria for observations: Use qualitative characteristics (color, shape, texture, smell, but **NO TASTING!**) and quantitative characteristics (data resulting in values/numbers); based on facts, NOT opinions.

17. After groups have time to brainstorm, have a whole-class discussion of the appropriate types of data to collect. You may want to discuss the benefits of conducting multiple trials in an experiment. Ask, “How can we use math to help describe and measure this scale of filtration?” Facilitate a class discussion on the importance of conducting multiple trials to validate results. *ESRs: We can collect data on the amount of water going into the filter and how much is coming out. We can compare the color before and after the filtration process. We can repeat our process multiple times.*
18. Ask table groups to make a prediction stating why their plan will work. They should explain why each part of their plan will work to separate substances from the water. Students should justify the order of their steps in terms of why they think it will allow for the separation of each substance. You can provide this sentence frame to guide them:

If I _____, then _____ would happen because _____ has shown to be effective for this phase of the solution to the problem.

TEACHER NOTE

Differentiation strategy

If students are familiar with the crosscutting concept Systems and System Models, then a sketch of their process can be drawn as a system, the components labeled, and the interactions described instead of writing out the specifics for each part of their system.

Explain 2 (45 minutes)

Analyze and interpret plans to identify materials based on their properties.

TEACHER NOTE

By the end of grade 5, students are expected to have the skill to “respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.”

For more information on this SEP, read chapters 11 and 13 of *Helping Students Make Sense of the World Using Next Generation Science and Engineering Practices* by Christina Schwarz, Cynthia Passmore, and Brian J. Reiser.

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19. Conduct a table group feedback review of the plans (similar to a gallery walk). One group member remains at the table to present the plan to visiting classmates and receive feedback/questions while other group members visit different groups to provide feedback on their proposed procedures.
20. Direct students to use green sticky notes to identify where the plans are valid and to use yellow sticky notes to write probing questions where the plans need more thought. Circulate, providing feedback and asking probing questions as needed.
21. Hand out **5.4.H5: Rubric** and tell students to consider only the first two rows at this time (defining problems and developing and using models). Ask table groups to reconvene, consider their peer feedback, and use the descriptions on the rubric to modify their plan.
22. Tell table groups that they will address the rest of the rubric and complete the remaining boxes on **5.4.H3: Environmental Engineer Design Plan** in the next lesson.

Elaborate/Evaluate (40 minutes)

Communicate information including a model for a design solution to identify materials in a sugar water solution.

23. Ask students to write in their science notebook a reflection on what they have learned about the engineering design process. If they have any new questions, ask them to write them on a sticky note and place them on a parking lot poster.

TEACHER NOTE

At the end of the entire sequence (after Lesson 5: Separating Mixtures), address the questions on the parking lot sticky notes by asking students to research online for answers or by having an engineer come to talk with students to address the questions.

24. Add the agreed-upon problem, criteria, and constraints to the third section of the Design Solutions Question Board (cleaning the water). In Lesson 5: Separating Mixtures, the student-designed plans will be tested and results will be added as final pieces of evidence.
25. ► Have students individually complete **5.4.H4: Sugar Water** to demonstrate their understanding of:
 - a. a small quantity of matter (sugar) existing in a larger quantity of other matter (water)
 - b. how to draw a model demonstrating their understanding
 - c. designing a process to provide evidence
26. Write the letters A-F on the board, leaving space to record the numbers of students who chose each. Then ask those who chose A to stand and choose one or two to explain their reasoning. Repeat for all answers thru F. (The correct answers are C, D, & F.). Explain to students that in grades 6–8 they will continue to build their understanding about what happens to substances when they are dissolved in a mixture.

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27. Collect **5.4.H4: Sugar Water** and review the student responses. The responses will provide you with information as to what the students still do not understand about mixtures.

References

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Keeley, P., & Tugel, P. (2012). *Uncovering Student Ideas in Science, Volume 4: 25 New Formative Assessment Probes*. Arlington, VA: NSTA Press.

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Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). Chapters 11 and 13. In *Helping Students Make Sense of the World Using Next Generation Science and Engineering Practices*. Arlington, VA: NSTA Press, National Science Teachers Association.

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Separating Mixtures

A **mixture** is a substance made by combining two or more different materials. The materials maintain their original properties when mixed in such a way that no chemical reaction occurs. A **mixture** can usually be separated back into its original components. Some examples of **mixtures** are a tossed salad, a basket of different fruits and vegetables, a toy box filled with toys, and dust in the air.

In the gold rush days in California, miners separated gold from the mixture of gold, dirt, water, and sand in streams and rivers. The gold was heavier than the sand and the dirt, so the miners developed different ways of getting the gold to settle to the bottom of their device while washing away the dirt and sand.

There are many different ways that mixtures can be separated. Three of the separation processes are filtration, distillation, and evaporation.

One method for separation is **filtration**. It uses a filter such as paper or sand to allow a liquid or gas to pass through. This traps the solids or impurities on the filter. When you make coffee in the morning, the grinds (solid) are trapped by the filter, as the water (liquid) passes through the beans to make the coffee. There are many types of filters. Some are also used to trap dust in our homes and businesses. Others remove impurities from our drinking water. Face masks filter bacteria and germs so we don't breathe them in. Even our bodies have filters—for example, the hairs in our nasal passages prevent impurities from reaching our lungs. Our kidneys and liver filter the impurities in our blood.

The **filtration process** is the process by which a mixture (small solid particles in water or air) are separated. When filtering water, the water is forced through paper or another material that is made up of a tiny fine mesh of fibers. This lets the water pass through while trapping the small particles. The particles removed from the water by the filter are called the **residue**.

Distillation, another method for the separation process, uses boiling to separate liquid mixtures. Different substances often have different boiling points, which means they boil at different temperatures. For example, water boils at 100°C, and linseed oil boils at 287°C. If you heat saltwater to boiling, the water will turn into steam and leave the salt crystals behind. If the steam from the boiling salt water is allowed to cool, it will form droplets of fresh water, without salt. One example of distillation is converting saltwater into drinking water. Another example of distillation is heating crude oil to separate it into its many components such as jet fuel, engine oil, and gasoline.

Evaporation is the process by which a liquid changes from a liquid to a gas (vapor). Some examples of evaporation are wet clothes drying in the sun on a clothesline, drying of wet hair, and hot tea getting cold. Our bodies use the evaporation of sweat to cool us. Removing salt from ocean water can be achieved through distillation AND through the evaporation process.

Exit Ticket

1. How does understanding properties of matter help us to use filtration to identify materials?
2. How did the crystals and residue form in the cups that were left out from the last lesson?
3. Predict what would happen if a mixture of sand and water was left to evaporate.
4. Based on your learning so far, what suggestions would you give city leaders regarding the town's drinking water problem?

Environmental Engineer Design Plan (for cleaning water samples)

1. Identify the problem.

The problem is

2. Define what you are asked to do (the criteria).

Our environmental engineer team has been asked to

3. Define the limitations or requirements (the constraints) necessary to solve the problem.

4. Apply scientific information have you learned from previous lessons and the reading to help you solve the problem.

Environmental Engineer Design Plan (continued)

5. Create a plan. Write detailed steps.

6. Revise your plan.

Environmental Engineer Design Plan (continued)

7. Carry out your plan and record your observations and results. You will use these results to make a claim.
Observations and results:

8. Compare your observations and results with those of another group. Which plan or parts of your plan worked more efficiently? Which parts did not work well?

Our plan met the criteria or was efficient at _____ based on these observations:

Our plan did not meet the criteria or was less efficient at _____ based on these observations:

Sugar Water

Deanna stirred a teaspoon of sugar (5 grams) into a glass of warm water (200 grams). The sugar completely dissolved in the water. Put an "X" next to the statements that are true about the dissolved sugar.

- _____ A The sugar melts.
- _____ B The sugar turns into water particles.
- _____ C The sugar forms a mixture with the water.
- _____ D The sugar can be separated from the water.
- _____ E The sugar disappears and no longer exists.
- _____ F The sugar particles are spread among the water particles.

1. Draw a model to explain what happens when sugar dissolves in water. Include both the visible and invisible parts, labels, and amount.



Rubric

NGSS Rubric	Beginning	Progressing	Proficient	Advanced
<p>Defining problems Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints.</p>	We understood the design problem.	We understood the design problem. We paid attention to some of the constraints of the problem. We used some science knowledge to find possible solutions.	We had a good understanding of the design problem. We paid attention to multiple criteria and constraints. We used science knowledge to find possible solutions.	We had an exceptional understanding of the design problem and could clearly articulate it. We paid attention to multiple criteria and constraints and understood the relationships between them. We used science knowledge and could clearly explain the science behind our design.
<p>Developing and using models Develop or modify a model—based on evidence—to explain the phenomena</p>	We created a model of what we thought was in the jars. For example, we saw the jars, and we drew a picture of the jars with some labels.	We created a model of the jars and revised it to show what was really in the jars. We added labels.	We created and revised a model of our jars. We understood and could name all the substances. Our model accurately represents the relationships among the parts of the proposed solution.	We created and revised a model of our jars. We could identify all the substances and their relationships within the solution. Our model explained the relationship between each of the parts and addressed the accuracy and limitations of the model.
<p>Planning and carrying out investigations Collect data about the performance of a proposed object. Evaluate the accuracy of various methods for collecting data.</p>	We collected qualitative performance data of the tools used to filter the solutions for a single trial.	We collected qualitative performance data of the tools used to filter the solutions for a single trial. We evaluated the accuracy of some of the tools used to filter the solutions.	We collected quantitative and qualitative performance data of the tools used to filter the solutions using multiple trials. We evaluated the accuracy of the tools used to filter the solutions.	We collected quantitative and qualitative performance data of the tools used to filter the solution using multiple trials and models of the tools. We evaluated the accuracy of different models of the same tool used to filter the solutions.

Rubric (continued)

NGSS Rubric	Beginning	Progressing	Proficient	Advanced
<p>Analyzing and interpreting data</p> <p>Analyze data to define an optimal process or system that best meets criteria for success. Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data and methods (e.g., multiple trials).</p>	<p>We analyzed the data of the single trial.</p>	<p>We analyzed the performance data of the single trial.</p> <p>We considered the limitations of our data collection.</p>	<p>We analyzed the performance data from multiple trials.</p> <p>We considered the limitations of our data collection and analysis.</p>	<p>We analyzed the performance data from multiple trials to refine the design of the tools used to filter the solutions.</p> <p>We created and/or used different tools to improve the precision and accuracy of the data.</p>
<p>Using mathematics and computational thinking</p> <p>Decide if qualitative or quantitative data are best to determine whether a proposed tool meets the criteria for success.</p> <p>Apply mathematical concepts (e.g., ratio, rate, percent, measurement, time) to solve problems.</p>	<p>We found a good solution to the design problem using trial and error.</p>	<p>We used some digital tools and/or mathematical concepts to qualitatively evaluate a proposed design solution.</p>	<p>We used appropriate quantitative mathematical tools and/or concepts to design and evaluate the proposed solution.</p>	<p>We used appropriate mathematical concepts to design and quantitatively evaluate different tools used to solve the same problem.</p>

Rubric (continued)

NGSS Rubric	Beginning	Progressing	Proficient	Advanced
<p>Designing solutions Apply scientific ideas to solve design problems. Use evidence to design a solution to a problem.</p>	<p>We proposed a design solution that meets some criteria and constraints.</p>	<p>We proposed a design solution that meets the criteria and constraints and is based on scientific ideas.</p>	<p>We proposed a design solution that meets the criteria and constraints, and using data, clearly supports the scientific basis for the design using data.</p>	<p>We proposed a design solution that meets the criteria and constraints and compares supporting data from more than one proposed design solution.</p>

Appendix 5.4

Cleaning Water

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
5-PS1-3	Make observations and measurements to identify materials based on their properties. <i>[Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.]</i> <i>[Assessment Boundary: Assessment does not include density or distinguishing mass and weight.]</i>
3-5 ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Asking Questions and Defining Problems
<ul style="list-style-type: none">• Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.• Use prior knowledge to describe problems that can be solved.• Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on material, time, or cost.
Planning and Carrying Out Investigations
<ul style="list-style-type: none">• Make observations and /or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or to test a design solution.
Analyzing and Interpreting Data
<ul style="list-style-type: none">• Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and /or computation.• Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
Constructing Explanations and Designing Solutions
<ul style="list-style-type: none">• Apply scientific ideas to solve problems.• Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
Obtaining, Evaluating, and Communicating Information
<ul style="list-style-type: none">• Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.• Communicate scientific and/or technical information orally and/or in written formats, including various forms of media, as well as table, diagrams and charts.

Appendix 5.4

DISCIPLINARY CORE IDEAS (DCI)

PS1.A: Structure and Properties of Matter

- Measurements of a variety of properties can be used to identify materials.
- 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.

ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specific criteria for success or how well each takes the constraints into account.

ETS1.B: Developing Possible Solutions

- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

CROSCUTTING CONCEPTS (CCC)

Patterns

- Identify similarities and differences in order to sort and classify natural objects and designed products.
- Identify patterns related to time, including simple rates of change and cycles and use these patterns to make predictions.

Scale, Proportion, and Quantity

- Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.

Influence of Engineering, Technology, and Science on Society and the Natural World

- People's needs and wants change over time, as do their demands for new and improved technologies.

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Common Core State Standards (CCSS)

CCSS ELA WRITING

CCSS.ELA-LITERACY.W.5.8

Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.

CCSS.ELA-LITERACY.W.5.9

Draw evidence from literary or informational texts to support analysis, reflection, and research.

Appendix 5.4

MATHEMATICS PRACTICES

MP.2

Reason abstractly and quantitatively.

MP.5

Use appropriate tools strategically.

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California English Language Development (ELD) Standards

CA ELD

Part 1.5.3 Offering opinions and evaluating others' opinions in speaking and writing.

EMERGING	EXPANDING	BRIDGING
Negotiate with or persuade others in conversations using basic learned phrases (e.g., <i>I think . . .</i>), as well as open responses, in order to gain and/or hold the floor.	Negotiate with or persuade others in conversations using an expanded set of learned phrases (e.g., <i>I agree with X, but . . .</i>), as well as open responses, in order to gain and/or hold the floor, provide counter-arguments, etc.	Negotiate with or persuade others in conversations using a variety of learned phrases (e.g., <i>That's an interesting idea. However . . .</i>), as well as open responses, in order to gain and/or hold the floor, provide counter-arguments, elaborate on an idea, etc.

In addition to the standard above, you may find that you touch on the following standard as well:

P1.5.1 Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics.

P1.5.2 Reading closely informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language.

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Image via iStock.com/Alex_Dobovitsky



Anchoring Phenomenon

Sewage water is consumed by people, but they do not get sick.



Lesson Concept

Compare multiple design solutions and their merit for separating substances from a mixture.



Identified Problem

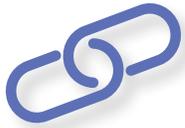
Water collected from a town may be contaminated. The town officials are requesting help to design a process that will identify the particles in the water and then clean the water.



Standards

Refer to Appendix 5.5 for NGSS, CCSS–ELA, and California ELD standards.

5.5 Separating Mixtures



Storyline Link

In the last lesson, students investigated filtration and evaporation as two processes that could clean the town water samples. Students began to use an engineering design process which included defining criteria and constraints.

This lesson focuses on students using all the information they have gathered regarding the properties of matter to build a process or system to identify and separate the materials in a town water sample.

Students will also evaluate their processes for success in meeting the criteria and constraints and compare their results to the results of other teams' processes. By the end of this lesson, students will be closer to understanding the anchoring phenomenon that sewage water can be processed so that it is drinkable.

TEACHER NOTE

The intent of this lesson is to allow students to determine their own design for separating the mixture. Their plan should include these components:

- iron filings can be separated with a magnet.
- sand will not dissolve in water so it can be filtered out of the mixture.
- salt dissolves in water and thus it can be removed through evaporation.

Discussions should include:

- How do we know if we got it all? (with references to what they did in Lesson 3: Properties of Matter using weight as a property of matter)
- How do we know if it's sugar or salt? (with a focus the idea that they should research how they might separate the two if they are both in the mixture)



Time

4 hours 35 minutes

30 minutes	Engage
60 minutes	Explore Plus overnight—or longer—for evaporation
60 minutes	Explain 1
45 minutes	Explain 2
45 minutes	Elaborate
35 minutes	Evaluate

5.5 Separating Mixtures



Materials

Whole Class (same materials as Lesson 4: Cleaning Water)

- Chart paper
- Town Water Samples (from Lesson 1: Town Water Samples)
- 20 paper bowls
- 20 8-oz. clear plastic cups
- 20 4-in. screen squares
- 20 4-in. pieces of cheesecloth
- 20 small shallow plastic bowls
- 2 1-quart water containers
- 20 plastic spoons
- 20 1-in. round magnets
- 20 coffee filters
- 1 paper towel roll
- 30 hand lenses
- 12 3-oz. cups
- 4 digital kitchen scale
- 15 tablespoons (kitchen measuring type)
- 5.5.C1: Criteria for Observations

Group (Groups of 2)

- 1 16-oz. plastic or paper cup
- $\frac{1}{8}$ cup of sand
- $\frac{1}{8}$ cup of salt
- $\frac{1}{8}$ cup of iron filings
- 3 3-oz. cups
- 2 tsp. sand
- 2 tsp. salt
- 2 tsp. iron filings
- 2 whiteboards

5.5 Separating Mixtures

Individual

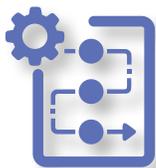
- Science notebook
- 5.4.H3: Environmental Engineer Design Plan (from Lesson 4: Cleaning Water)
- 5.4.H5: Rubric (from Lesson 4: Cleaning Water)



Advance Preparation

1. For each set of partners, mix $\frac{1}{8}$ cup of each substance (sand, salt, iron filings) in the large plastic cup; add $1\frac{1}{2}$ cups of water and stir well. (This is the mixture to be separated.)
2. Set up a side table or counter with the supplies for the Explore (hand lenses, magnets, water, 3-oz. cups, and spoons).
3. For each set of partners, set up 3 cups (3-oz.). In one cup, have 1 tsp. of sand, in another cup have 1 tsp. of salt, and in the third cup have 1 tsp. of iron filings.
4. Make a chart similar to **5.5.C1: Criteria for Observations**.

5.5 Separating Mixtures



Procedure

Engage (30 minutes)

Define a simple design problem to identify and separate materials based on their properties.

1. Hold up Town Water Sample #2 and explain that this is the sample the town wants cleaned first. Ask students to work with a partner to review their science notebook entries from all of the lessons. What do they know about Town Water Sample #2? *ESRs: From our models in Lesson 1: Town Water Samples and Lesson 2: Finding Impurities in Water, we know that there are observable particles in the water: sand and black things which we now think are iron filings. From our exploration in Lesson 3: Properties of Matter where we used the indicator, we know that there are other particles too small to be seen. We also know that the police found empty bags of iron filings, sand, salt, and sugar. So, there may be particles that are too small to be seen such as salt or sugar or even something else.*
2. Ask table groups to discuss this question: “Based on what you think might be in Town Water Sample #2, what properties of matter might you use for your design? Ask several groups to share their thinking and give groups a moment to add any new ideas to their plan.
3. To help you in your design, you can review some of possible contaminants in the water sample. Distribute the 3-oz. cups so that each table has one of sand, one of salt, and one of iron. Give students time to review each of the substances and their properties. Make a 3-column table on the board with these headings: Sand, Salt, and Iron. Have students review in their science notebook the properties of the substances and record their ideas regarding the basic properties in each of the columns.

Sand	Salt	Iron
Does not dissolve in water	Dissolves in water	Does not dissolve in water
Grainy, gritty	Grainy	Grainy
Not magnetic	Not magnetic	Magnetic

4. Ask the students to review their table group’s plan recorded on **5.4.H3: Environmental Engineer Design Plan** to get the matter separated and identified. Now that they know the Town Water Sample is #2, does their plan still work? How will knowing the properties of the materials affect the engineer design plan? Does it still meet the criteria and constraints?
5. After their discussion, ask partners to share any ideas they have about changing or refining their plan.
6. Ask the class if they have any questions and record the student questions so that everyone can see them on the Class Question Board.

5.5 Separating Mixtures

TEACHER NOTE

Facilitate student discussion and push students to “Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.”

Explore (60 minutes plus overnight to allow evaporation)

Apply scientific ideas to solve design problems and to gather data on substances based on their unique properties.

7. Review with the students the materials on the table that are available for creating their solution.
8. Ask partners to use a whiteboard to draw their “plan of action.” What will they do first? What materials will they use and why? What will they do next? What materials will they use and why?
9. Ask each set of partners to share with another set of partners their diagram and explanation of their plan.

TEACHER NOTE

Facilitate the student planning and discussion by asking specific questions about the materials they are using, what might happen if a different material was used, and why they think the material they have chosen is the best for a specific purpose. Provide these sentence frames:

We will use _____. It is the best choice because _____. If we use _____ instead, then _____.

This will facilitate the discussion with another set of partners when they share their plans.

10. After sharing, ask partners to make any final changes to their design and record it in the box labeled #6 Revised Plan on **5.4.H3: Environmental Engineer Design Plan**.
11. Ask student to gather materials and set up their design solution. When the design is complete and ready for testing, give the students the large plastic cup containing the Town Water Sample (Step 1 in Advance Preparation). Ask students to record their observations and results in the box labeled #7 on **5.4.H3: Environmental Engineer Design Plan**. Ask partners to refer to **5.5.C1: Criteria for Observations** to support their recording of their observations.

TEACHER NOTE

The student design should include evaporation of the remaining liquid. Allow time for the liquid to stay out at least overnight and preferably over the weekend.

5.5 Separating Mixtures

Explain 1 (60 minutes)

Generate and compare multiple solutions to a problem using the properties of matter to clean a water system.

12. Have partners return to their table group. Ask them to compare their observations and results with the criteria and constraints and complete the box labeled #8 on **5.4.H3: Environmental Engineer Design Plan**. Post these questions on a doc camera to help them with their discussion:
 - Why did you use this particular material? How did it work? What is your data?
 - What might be a better material to use?
 - Please explain to me how your design system works.
13. Have a whole-class discussion of these questions.
14. Challenge the class to think about:
 - a. "Is the residue from the evaporation salt or sugar? What information is needed to answer this question?" Chart their ideas.
 - b. "How efficient was their separation? Did they get back everything they started with? What information is needed to answer this question?" Chart their ideas.

TEACHER NOTE

Efficiency means how well the substances were separated. Efficiency can be evaluated by determining which team recovered the most of each substance separated with the least amount of impurities.

Reflecting on Lesson 4: Cleaning Water, efficiency should include the idea that the separated weight and volume for each type of matter removed is the same as the starting weight and volume of the Town Water Sample.

- c. Select a question from the Design Solutions Question Board or Class Question Board that would be interesting for student to discuss. What information do they need to answer this question? Chart their ideas.
15. Allow students to select the question they want to work on from either question board, and provide time for students to research how they might answer that question. After they have recorded their ideas in their science notebook, have them assemble in groups (based on those who worked with the same question) to share their ideas.
16. Ask each group to make a brief presentation of their findings to the whole class.

5.5 Separating Mixtures

Explain 2 (45 minutes)

Generate and compare *multiple solutions to a problem using the properties of matter to clean a water system.*

17. Ask students to individually write in their science notebook reflecting on the different design processes created by their peers and the data showing how each design worked in separating the various matter in the water samples. Based on the comparison of different designs, ask students to write ideas for a best design solution for separating the substances and describe why they propose the plan, tools, and materials for separating the substances.
18. Students share ideas as a class and add evidence to the Class Question Board and Design Solutions Question Board.
19. ► (Self-assessment) Ask table groups to reflect on their process for their design by referring to **5.4.H5: Rubric** (from Lesson 4: Cleaning Water). Ask them to reflect on the last four components (planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, and designing solutions).

Elaborate (45 minutes)

Compare solutions used to separate substances based on their unique properties.

20. Provide the class with Town Water Samples #1 and #3. Ask students to think about what they learned about matter separation in sample #2. Then, in their science notebook, ask them to pick either sample #1 or #3 and describe how they would separate the matter from the water.
21. Divide the class into sample #1 and sample #3 groups and then into smaller groups of four. Have students discuss their ideas for separating their mixture. Ask them to choose the best idea.
22. Ask groups from #1 and from #3 to share their ideas with the class, explaining which process would be the best and why.

Evaluate (35 minutes)

Make a claim about the merit of a solution and communicate solutions to clean and identify matter in contaminated water.

23. Have students work in pairs to discuss what they learned from separating the mixture in Town Water Sample #2. Based on that information, they must develop an explanation that describes how a water filter works. They should include their understanding of:
 - particle size
 - the properties of materials that are used to identify them
 - the scale of the filter, water, and contaminants

5.5 Separating Mixtures

24. Have each pair make a poster to display outside the classroom, so that others can understand how a water filter works. Hang the posters around the school to make other students aware that contaminated water can be cleaned.
25. ▶ Ask students to reflect in their science notebook how understanding the properties of matter and identification of matter helps them understand the anchoring phenomenon that sewage water can be made drinkable. They should state that water filtration makes sewage water safe.

TEACHER NOTE

- ▶ Use the posters to assess students' understanding of water filtration.

Toolbox Table of Contents

5.5.C1 Criteria for Observations

5.5.11

Criteria for Observations

- Uses as many senses as appropriate to make observations.
- Uses qualitative characteristics (e.g., color, shape, texture, smell).
- Uses quantitative measurements with the appropriate tools and units of measure (non-standard or standard) such as pH, temperature, time, and Moh's hardness scale.
- Based on facts, not opinions.
- Contains no inferences or explanations.
- Uses appropriate vocabulary related to content.

Appendix 5.5

Separating Mixtures

Next Generation Science Standards (NGSS)

This lesson is building toward:

PERFORMANCE EXPECTATIONS (PE)	
5-PS1-3	Make observations and measurements to identify materials based on their properties. <i>[Clarification Statement: Examples of materials to be identified could include baking soda and other powders, metals, minerals, and liquids. Examples of properties could include color, hardness, reflectivity, electrical conductivity, thermal conductivity, response to magnetic forces, and solubility; density is not intended as an identifiable property.] [Assessment Boundary: Assessment does not include density or distinguishing mass and weight.]</i>
3-5 ETS1-1	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
3-5 ETS1-2	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

SCIENCE AND ENGINEERING PRACTICES (SEP)
Asking Questions and Defining Problems
<ul style="list-style-type: none">Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on material, time, or cost.
Planning and Carrying Out Investigations
<ul style="list-style-type: none">Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.Test two different models of the same proposed object, tool or process to determine which better meets criteria for success.
Analyzing and Interpreting Data
<ul style="list-style-type: none">Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and /or computation.Compare and contrast data collect by different groups in order to discuss similarities and differences in their findings.
Constructing Explanations and Designing Solutions
<ul style="list-style-type: none">Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design solution to a problem.Identify the evidence that supports particular points to an explanation.Apply scientific ideas to solve design problems.

Appendix 5.5

DISCIPLINARY CORE IDEAS (DCI)

PS1.A: Structure and Properties of Matter

- Measurements of a variety of properties can be used to identify materials.
- 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.

ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

ETS1.B: Developing Possible Solutions

- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

CROSSCUTTING CONCEPTS (CCC)

Systems and System Models

- A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.

Patterns

- Similarities and differences in patterns can be used to sort, classify, communicate and ~~analyze simple rate of change for natural phenomena and designed products.~~

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Common Core State Standards (CCSS)

CCSS ELA SPEAKING AND LISTENING

CCSS.ELA-LITERACY.SL.5.1

Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

- Follow agreed-upon rules for discussions and carry out assigned roles.
- Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.
- Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.

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Appendix 5.5

California English Language Development (ELD) Standards

CA ELD		
Part 1.5.6a Reading/viewing closely		
EMERGING	EXPANDING	BRIDGING
a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with substantial support.	a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with moderate support.	a) Explain ideas, phenomena, processes, and text relationships (e.g., compare/contrast, cause/effect, problem/solution) based on close reading of a variety of grade-level texts and viewing of multimedia with light support.
In addition to the standard above, you may find that you touch on the following standard as well: P1.5.1 Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics		

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