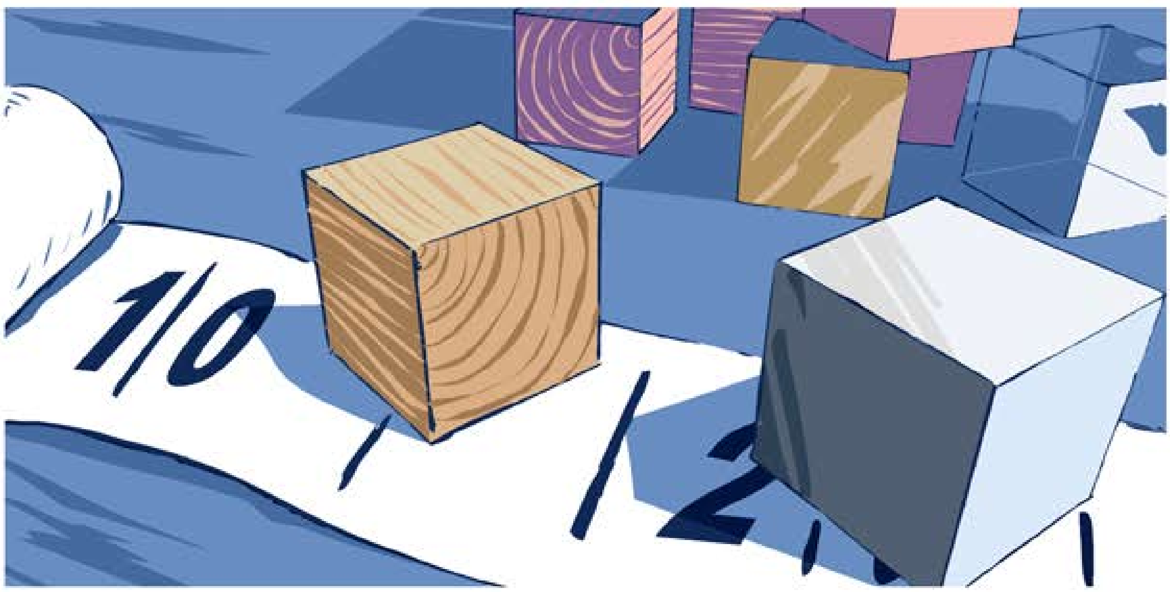
Grade 3

The Inquiry Project

Seeing the world through a scientist's eyes

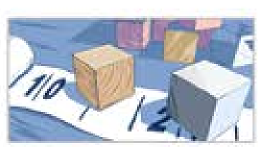


Grade 3

Investigating Things in My World

Observing and Measuring Materials and Objects

TERC



Grade 3

Grade 4

Grade 5

The Inquiry Project

Seeing the world through a scientist's eyes

This curriculum was developed by TERC, Cambridge, Massachusetts 02140 www.terc.edu. TERC is a not-for-profit education research and development organization dedicated to improving mathematics, science, and technology teaching and learning.

This material is based on work supported by the National Science Foundation under Grant No. DRL-0628245. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect views of the National Science Foundation.

ISBN 978-1482648621

www.terc.edu

Table of Contents

What is the Inquiry Curriculum …… 3
- The Curriculum (Grades 3-5) …… 3
- Curriculum Resources …… 3
- How the Curriculum Works …… 4
- Meeting the Vision of the NRC Framework and NGSS Science Standards …… 4
- Central Inquiry Science Concepts …… 5
- What information about the Inquiry Curriculum is on the website …… 5

Overview of Grade 3 Curriculum …… 6

Curriculum at a Glance Chart …… 7

1. Investigating Materials …… 9
   - The Child's Ideas: The Challenges in Learning about Materials …… 10
   - The Scientist's Essay: Why are Material Properties Important? …… 11
   - Investigation 1: What are things in my world made of? …… 12
   - Investigation 2: What kind of material makes an object work well? …… 17
   - Investigation 3: How are materials the same and different? …… 22
   - Investigation 4: How can we sort cubes that are all the same size? …… 27
     - Materials Concept Cartoon …… 31
   - Investigation 5: How do materials help us in our classroom? …… 34

2. Investigating Weight …… 39
   - The Child's Ideas: The Challenges in Learning about Weight …… 40
   - The Scientist's Essay: Why is Weight Important? …… 41
   - Investigation 1: How good are our senses at comparing the weights of the cubes? …… 42
   - Investigation 2: What does a pan balance tell us about the weight order of the cubes? …… 46
   - Investigation 3: How can we measure the weights of our cubes? …… 51
   - Investigation 4: How much heavier is one cube than another? …… 55
     - Weight Concept Cartoon …… 60

3. Investigating Standard Measures …… 63
   - The Child's Ideas: The Challenges in Learning about Weight Measurement …… 64
   - The Scientist's Essay: Why are Standard Measures Important? …… 65
   - Investigation 1: How can grams help us compare weights? …… 66
   - Investigation 2: How much do the cubes weight in grams? …… 70
   - Investigation 3: Do very tiny thins have weight? …… 74
     - Standard Measure Concept Cartoon …… 79
   - Investigation 4: The 10-10-10-10 Challenge …… 81

4. Investigation Volume 85

The Child's Ideas: The Challenges in Learning about Volume 86

The Scientist's Essay: Why is Volume Important? 87

Investigation 1: What does it mean to take up space? 88

Investigation 2: How can centimeter cubes help us measure volume? 92

Investigation 3: Does changing the shape of an object change its volume? 97

Volume Concept Cartoon 102

Investigation 4: How can we describe our personal objects? 106

Resources 112

Science Background 112

Curriculum Kit 113

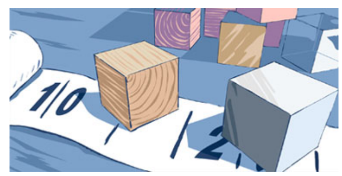
What is the Inquiry Project?

The Inquiry Project brings together research, curriculum, assessment, and professional development to deepen students understanding of the nature of matter.

The Curriculum (Grades 3–5)

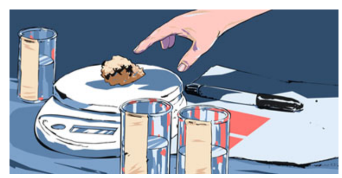
In the Inquiry Curriculum, Grade 3–5 students learn core ideas, scientific practices, and crosscutting concepts to progressively build a rich network of experiences and understanding about the structure and properties of matter. The concepts of **material, weight, volume, and matter** are emphasized as these ideas are essential for all of science and provide the necessary foundation for robust understanding of the particulate model of matter in later grades.

Students use scientific practices that are central to inquiry such as reasoning from evidence, building and using models, and developing explanations. They learn crosscutting concepts that span the disciplines of science, such as system and scale. They work collaboratively with their classmates and teachers, using measurement, mathematical and graphical representations, and discussion to build scientific explanations about objects and materials in the world around them.



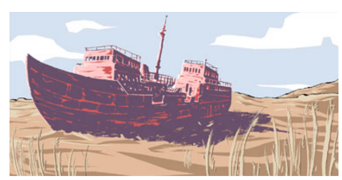
Grade 3: Investigating Things in My World

In grade 3, investigations of weight and material are front and center and volume is introduced briefly at the end of the unit. Within their investigations, students learn to use data tables and measure lines to represent weight. They express their ideas through discussions, writing, and drawing.



Grade 4: Investigating Earth Materials

In grade 4, students investigate properties of earth materials. They learn to distinguish and measure weight and volume and investigate their relationships in different solid and liquid materials. By the end of grade 4, students ask which properties of matter stay the same during transformations such as crushing (weathering) and reshaping, and which properties do not.



Grade 5: Investigating Water Transformations

In grade 5, students investigate properties of gases. They deepen their understanding of matter as they investigate phase change and transformations of water as it freezes, melts, evaporates, and condenses. By the end of grade 5, students are able to describe transformations of water at two scales: the macroscopic or visual scale and in terms of particles that are way too small to see.

Curriculum Resources

- A teachers' guide
- Student notebook
- A materials kit for student investigations
- A "Curriculum at a Glance" chart
- Embedded assessments
- Child and Scientist Essays (background information)
- Cross-grade concept chart
- Video introduction to the curriculum (on inquiryproject.terc.edu)

How the Curriculum Works

Each lesson within the curriculum is called an investigation and each unit consists of 16 or 17 investigations. Each investigation (a) introduces an Investigation Question, (b) includes an exploration or data gathering activity, and (c) wraps up with a class discussion so students can make meaning of their work and have a chance to clarify their understanding through talking and listening. Throughout the lesson, students write in their science notebooks, for example, recording their ideas, predictions, and measurements, representing their findings, and proposing explanations.

A complete investigation takes about 50-60 minutes and includes both the firsthand science experiences, literacy-related notebook writing, and whole class discussion. When science classes are scheduled for 45 minutes, teachers are encouraged to find an additional 15 minutes for students to complete their notebook writing or have an unhurried discussion where they practice articulating their ideas and explaining their reasoning.

The Research

The Inquiry Curriculum is based on extensive research about children's ideas and learning. It is also informed by a 3-year longitudinal study comparing the learning of grade 3-5 children who used the Inquiry Curriculum with those who did not. This study showed that children using the curriculum made more progress in moving from perception-based to model-mediated understanding of materials and matter. (Learn more at inquiryproject.terc.edu, Research Tab)

Formative Assessment Opportunities

The opportunities for assessment are endless in the Inquiry Curriculum. Anytime you observe what children do, listen to what they say, or review what they've written and drawn, there is opportunity to take account of their ideas and how these ideas are developing. However, watching, listening, and reviewing work must be done with specific questions and criteria in mind. In other words, you need to know explicitly what you are watching, listening, and reviewing work for.

Throughout the Inquiry Curriculum opportunities for assessment are identified and criteria, questions and guidelines for reviewing students' work are provided as part of the lesson description. These opportunities for assessment align with the learning goals, provide ongoing information about students' ideas and help to inform next steps in the learning for both teachers and students. **Student notebooks** and **Concept Cartoons** found within each unit are also opportunities for assessment. (Learn more at inquiryproject.terc.edu, Assessment Tab)

Professional Development Opportunities

Guidelines for facilitating **Curriculum Implementation Workshops** are provided for each curriculum unit. Through the implementation workshop you'll become familiar with the organization of a unit, its goals and specifics of each investigation. **Talk Science**, professional development is a web-based program aligned with the Inquiry Curriculum to increase the productivity of classroom science discussions. (See inquiryproject.terc.edu, PD Tab)

Meeting the Vision of the NRC Framework and NGSS Science Standards

Consistent with the new *Science Framework* and *Standards*, the Inquiry Curriculum emphasizes deeper understanding of core ideas, crosscutting concepts, and the practices of science and engineering. The new vision calls for increased coherence. In the Inquiry Curriculum, ideas, concepts and practices progress grade to grade with each supporting the other and developing systematically over multiple years. There is also coherence between curriculum, instruction, and assessment within each grade. Learn more about how the Inquiry Curriculum meets the new vision at: http://doingnewsciencestandards.org

Central Inquiry Science Concepts				
	Weight	**Volume**	**Material**	**Matter**
Grade 3	The weight of objects can be compared using a pan balance and standard (gram) units.	Two solid objects cannot occupy the same space. The amount of 3D space that objects occupy can be compared.	Objects can be described in terms of their weight and volume and the materials they are made of (clay, cloth, paper, etc.). Materials have observable physical properties such as color, size, texture, flexibility, etc. Same size objects can have different weights when they are made of different materials.	Materials can be subdivided into small pieces and the pieces still have weight.
Grade 4	The weight of solids and/or liquids can be compared using a digital scale and can be represented on a weight line or a table. Weight is conserved during crushing and reshaping.	Liquid and solid volumes can be measured in cubic centimeters. When immersed, a solid displaces a liquid volume equal to the solid volume.	The relationship between weight and volume (i.e. density) is a property of solid and liquid materials.	Matter can be divided into tiny pieces, and even the tiniest pieces have weight and take up space.
Grade 5	Weight is conserved during dissolving, freezing, melting, evaporation and condensation.	Volume may not be conserved in phase change.	Air is a mixture of gaseous materials composed of particles too small and spread apart to see. Melting, freezing, evaporation and condensation change the form of matter but do not change the material.	Matter is composed of particles that have weight, occupy space, and are too small to see. Gases, liquids and solids are all forms of matter and have weight and take up space.

What information about the Inquiry Curriculum is on the website?

There is no need to carry the teachers' manual home as the full curriculum and more is freely available on the Inquiry Project website (inquiryproject.terc.edu). On the web, you'll also find:

- Videos cases from classrooms engaged in the curriculum
- Video interviews with scientists that provide insight into scientists' thinking
- Formative assessment examples embedded within the curriculum
- PD support for leading productive discussions

Overview of Grade 3 Curriculum

Investigating Things in My World

Observing and Measuring Materials and Objects

The third grade curriculum has four strands that help set the foundation for a learning progression in the nature of matter. The first strand, Investigating Materials, helps students distinguish between objects and materials. Students build their understanding that objects in their daily lives are made of many different types of materials with different properties. The second strand, Investigating Weight, focuses on weight as a property of matter. Students make the transition from felt weight, perceived with their hands, to measured weight using a pan balance. The third strand, Investigating Standard Measures, has students share their measurements of weight with each other and introduces the need for a standard unit of measurement. The fourth strand, Investigating Volume, introduces volume as another important property of matter.

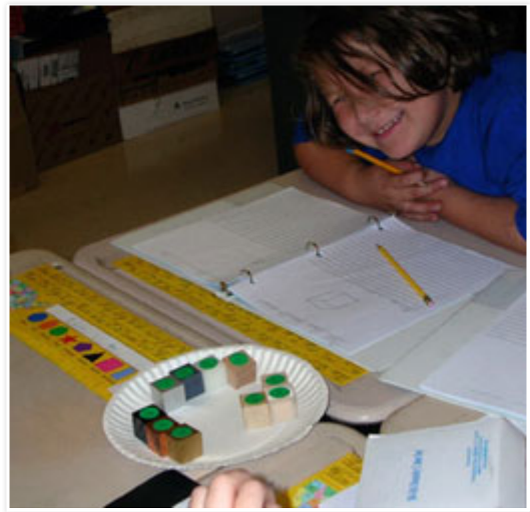
Embedded within these strands are the development of representations (most significantly, a number line used to represent weight) as well as scientific models and explanations through discussions, notebooks, and the use of concept cartoons.

Inquiry Project Grade 3 Curriculum

Investigating Things in My World: Observing and Measuring Materials and Objects

1. INVESTIGATING MATERIAL	2. INVESTIGATING WEIGHT	3. INVESTIGATING STANDARD MEASURE	4. INVESTIGATING VOLUME
1. What are things in my world made of? Learn to distinguish between an object and the material it is made of. Sort a collection of everyday objects by the materials they are made of. Then look generally at materials that make up the classroom.	**1. How good are our senses at comparing the weights of cubes?** Order the materials cubes by felt weight. Create need for measurement and introduce the pan balance.	**1. How can grams help us compare weights?** Introduce standard gram weights and practice using grams to weigh the cubes and other objects. Place objects on a gram weight line. Focus on the relationship between weight and size of objects.	**1. What does it mean to take up space?** Discuss the meaning of "taking up space" and contrast it with measurements such as length or height. Arrange a diverse set of objects in order by the amount of space they take up. Groups arrange their personal objects by estimated volume.
2. What kind of material makes an object work well? Describe objects by the kind(s) of material they are made of. Think about materials in terms of their usefulness to objects, including materials that make an object work well or badly.	**2. What does a pan balance tell us about the weight order of the cubes?** Use the pan balance to compare the weights of the materials cubes and check the order that was established by felt weight.	**2. How much do the cubes weigh in grams?** Weigh the cubes in grams and use the weight line to compare the weights of these same-sized samples of different materials. Bring forward the ideas of the additive and continuous nature of weight.	**2. How can centimeter cubes help us measure volume?** Arrange a set of four small wood blocks in order by estimated volume. Using plastic centimeter cubes, build replicas of each of the blocks to measure their volumes and check the estimated order. Establish cubic centimeter as standard unit of volume.
3. How are materials the same and different? Observe the materials in 2 cubes to determine how they are the same and how they are different. Introduce the idea of properties. Include the personal objects in this work.	**3. How can we measure the weights of our cubes?** Space the materials cubes by felt weight and then use uniform weights (paper clips, steel washers, and plastic bears) to compare the weights of the cubes.	**3. Do very tiny things have weight?** Continually halve an 8-gram piece of plasticene, at each step determining the weight, or, when very tiny, reasoning about whether the tiny pieces still have weight.	**3. Does changing the shape of an object change its volume?** Arrange 8 plastic centimeter cubes into a "domino" shape (2 cm x 5 cm x 1 cm) and build a plasticine replica. Using the entire 8 cc's of plasticine, form a variety of shapes or sculptures. Are the new shapes still 8 cc's in volume?
4. How can we sort cubes that are all the same size? Sort the set of materials cubes by their properties. Use the groupings to highlight the concept of organizing properties into categories **5. How do materials help us in our classroom?** Take a close look at the materials in one object, focusing on how the properties of each material work together to support the function of the object.	**4. How much heavier is one cube than another?** Use one of the three uniform weights (paper clips, steel washers, or bears) to determine relative weights of cubes.	**4. The 10-10-10-10 Challenge** Use grams as standard to measure weight. Experience measuring equal weights of different solid materials. Create something using 10 g each of 4 materials. Discussion: How do the sizes of each material vary for a 10 g weight? Some materials are heavier than others.	**4. How can we describe our personal objects?** Collect and record information about the personal objects: What materials are they made of? What are their weights and estimated volumes? Once this data is collected, students display it graphically and use the data to develop claims about the class-wide set of personal objects.

1. Investigating Materials

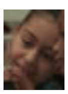


The objects in our world are made of many different materials, each having different properties. By exploring the similarities and differences between materials, students begin to see why some materials are better suited for some objects than others. They begin to distinguish objects by their properties with particular attention to weight and material. They come to understand that the tiniest pieces of a material have weight and are made of the same material as the object from which it comes, and that objects may be made of multiple materials.

Investigations:

1. What are things in my world made of?
2. What kind of material makes an object work well?
3. How are the materials the same and different?
4. How can we sort cubes that are all the same size?
5. How do materials help us in our classroom?

The Child and the Scientist



The Child:
The Challenges in Learning about Materials

The Scientist:
Why are Material Properties Important?

Concept Cartoon

The Materials Concept Cartoon is typically used as a formative assessment after Investigating Materials 4

Letters from the Engineer

While students use science practices to deepen their understanding of scientific ideas throughout this curriculum, some of their investigations bridge to the engineering world. To highlight some of the instances where students engage in an engineering practice or gain insight into the engineer's world, the curriculum includes *Letters from the Engineer*. Look for these letters (in the special boxes) and read them to the class.

The Child's Ideas for *1. Investigating Materials*

The Challenges in Learning about Materials

> "some of the most revealing properties of materials (e.g., their densities) are not ones that are directly given perceptually, but need careful construction"

In everyday life, we immediately see and describe the world in terms of its large-scale objects. For example, upon entering a classroom, you notice the desks, chairs, computers, books, lunch boxes and other objects as well as the fish tanks, plants, children and their teacher. We need to immediately recognize these things because we interact with them in distinctive and important ways in our daily life. For example, you eat your food, but not your computer; you sit on your chair but (generally) not on your desk; you water the plants but not your books; you talk to your classmates but not your chair, etc. In keeping with their importance, our visual systems are designed to automatically pick out the distinct objects in a visual scene and our language systems have a large number of words for naming types of objects at multiple levels of description (e.g., furniture, chairs, desk chairs; animals, dogs, Golden Retrievers) as well as their salient properties (large/small, red/green, hard/soft, cold/warm), ways of behaving (rolls, walks, talks, eats, swims), and functions (holds lunch, used for sitting, writing, reading, etc.). Words for types of objects, their properties, and simple actions involving them are among the very first words that children learn.

Much less *salient* to children, though ultimately no less important, is the world of "materials" of which objects are made. When we are naming materials, we are calling attention to another level of description—one that focuses on the kind of stuff something is a made of (a formless aggregate of a particular type) rather than the individual, whole object itself (which has a distinct shape and function and that we can pick up and play with). Thus, whether we call something "wood" depends on whether it has the cluster of properties that we think characterizes wood, not whether it is large or small or whether it is a spoon or a chair. The same objects can be made of different kinds of stuff, and the same kinds of stuff can be used to make different objects.

Young children are not clueless about materials—even preschoolers have some words for naming different types of materials (e.g., milk, sand, wood)—but their knowledge about materials is implicit (rather than explicit) and not yet coordinated with their knowledge about objects. Research has shown that the first names for kinds of material that children learn are for liquids (water, milk) rather than for solids (wood, metal, glass), although they may have a few such names by age three or four. This may be because of an "object bias" for solids. When you see a wooden spoon, what is most salient is the whole object and what you can do with it, not what is made of. In contrast, when you see a puddle or a glass of water, what is most salient is the stuff itself and its properties (you get wet if you go in it) not the shape of the puddle. Learning about the materials that objects are made of is important because it provides children an opportunity to coordinate these two levels of description and construct a more explicit concept of "made of."

Coming to understand and "see" the world in terms of the materials that objects are made of requires not only simple observation but also imagination, controlled thought and reasoning, careful inquiry and systematic investigation. Things that look different on the surface (if scratched or painted) could be made of the same material and some things that look superficially alike may in fact be made of different materials. As you cut something into smaller and smaller pieces, mold it, heat it or cool it, some of its observable properties change (it might go from being solid to a powder, from one shape to another, from something hard to something soft and runny). Is it still the same kind of material? How do we know?

Answering these questions is not simple, but involves active theory-building about materials, which is a long protracted process. It requires imagining and elaborating another level of description—the level of materials (wood, glass, plastic) that is distinct from the more salient whole object level of description (spoons, desks, trucks). And it involves explicitly coordinating these two descriptive levels when making such statements as “This truck is made of metal; This cup is made of plastic.” It requires learning about the distinctive properties of materials and then explaining some aspects of the behavior of objects in terms of the kinds of materials they are made of—for example learning that the cup breaks *because* it is made of glass or the ball bounces because it is rubber. Ultimately, some of the most revealing properties of materials (e.g., their densities) are not ones that are directly given perceptually, but need careful construction. Thus it requires that children move from initial, imprecise characterizations of properties of materials that conflate weight and density to more differentiated and precise characterizations in which weight and density are distinguished. Our units start children on this important process.

—Carol L. Smith

The Scientist’s Essay for *1. Investigating Materials*

Why are Material Properties Important?

Since science strives to describe and understand the world around us, the properties of the substances that comprise that world are of almost self-evident interest. As soon as we begin to focus on those properties, the list of intriguing questions is virtually endless:

> *Whether designing a bridge, a bookcase, a heart valve, a tennis racquet or a microchip, the engineer begins with a thorough understanding of the physical and chemical properties of the available materials.*

- Why do some materials float in water while others sink?
- Why are some materials transparent while others are opaque?
- Why do some materials feel cold to the touch while others don’t?
- Why do some materials conduct electricity and others don’t?
- Why do some liquids mix and stay mixed, while others separate?
- Why are a few materials attracted to magnets, while most aren’t?
- Why do some materials bend, while others break?
- How can a combination of two materials have properties unlike either of its constituents?
- What happens to a material’s properties when its temperature changes?

Answering these and similar questions has been a central and challenging area of scientific inquiry for centuries, and has led to the discovery of such surprising and unexpected phenomena as superconductivity. The current excitement about nanoscience centers on how the properties of materials change when the objects they comprise reach the scale of tens or hundreds of atoms.

From a practical standpoint, material properties are the starting point for engineering and technology. Imagine our world, for example, without plastics or semiconductors — materials that have been understood and exploited only for the past several decades. Whether designing a bridge, a bookcase, a heart valve, a tennis racquet or a microchip, the engineer begins with a thorough understanding of the physical and chemical properties of the available materials.

For any of these purposes, the first steps are careful preparation of materials of well-defined composition and quantitative measurement of the relevant properties, and large numbers of scientists and engineers spend the bulk of their time on those tasks.

—Roger Tobin

Investigating Materials 1:
What are things in my world made of?

Plan Investigating Materials 1

Scissors … windows … lunch boxes … sneakers. These are the kinds of objects that children see every day. They give them more attention than you might realize, and they have a lot of ideas about them – what they're made of, how they work, what they're worth.

In this investigation, you will explore some of your students' ideas about what things are made of and how different materials behave. You will help them distinguish between "objects" and "materials," and you will help them identify different kinds of materials, such as metal, plastic, and wood.

Formative Assessment

Can students distinguish between objects and the materials they are made of?

Available online at inquiryproject.terc.edu

Students will first explore a collection of everyday objects that you supply, including a paperclip, a pencil, a popsicle stick and a key. Then they will sort these objects into groups according to their materials. Students will also explore the classroom to notice additional objects and the materials from which they are made.

By the end of the investigation, the children will be looking around the classroom with the eyes of a scientist, wondering about the materials objects are made of.

Learning Goals

- to distinguish between an object (e.g., a key) and the material it is made of (e.g., metal)
- to understand that some objects (e.g., spoons) can be made of different materials (e.g., wood, metal, and plastic) and that some objects are made of more than one material (e.g., pencils)
- to observe and record details

Sequence of experiences		
1. Ask the question	Discussion	15 Mins
2. Sort objects by materials	Small Groups	15 Mins
3. Make meaning	All Class	10 Mins
4. Find a personal object	All Class	5 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Post the following title on a whiteboard or flip chart: "Materials and What We Know About Them."
- Set aside a separate set of materials for group discussion.

For each group:

- piece of cardboard, approx 2"x2"
- plastic-covered copper wire,approx 6" long
- bare copper wire; approx 6" long
- piece cotton cloth fabric, approx 2"x2"
- wooden spoon (ice cream type)
- metal spoon
- plastic spoon
- metal key
- steel bolt
- 3-oz paper cup
- rubber eraser
- plastic counting bear
- steel washer
- wooden coffee stirrer
- pencil

1. Ask the question

Discussion 15 Mins

"What are things in my world made of?"

Let the children talk freely about the question for a couple of minutes, providing only the most open-ended prompts, also in the form of questions:

What could this question mean?

How could we ever answer it?

What might a scientist do to answer this question?

Bring the discussion around to specific objects and materials. Look around the room and spot an object.

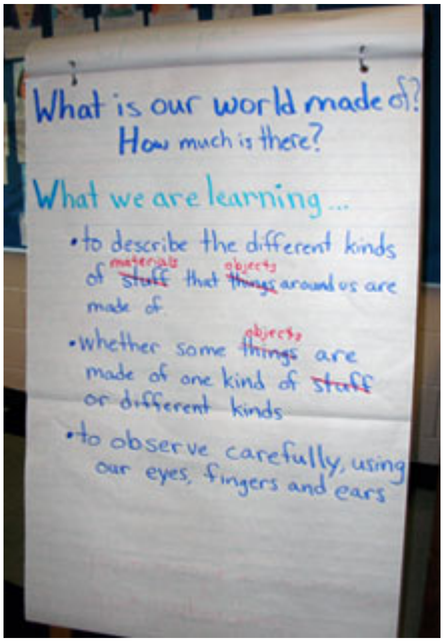
What stuff (or material) is it made of?

Model how you'd like students to first name the thing and then the stuff from which it is made. Use a couple of objects from the set that students will use.

- This object I'm holding is a block, and the material it's made of is wood.
- This is a small bear, and the stuff it's made of is plastic.

Note: Until you know what words the children are comfortable using, use non-technical ones and introduce the scientific terms later. In this first example, the terms "thing" and "stuff" will soon be replaced with the terms "object" and "material".

Continue eliciting examples until you are sure students understand the difference between *objects* and *materials*.



How one teacher started
Jen allowed time for her students to write their ideas about the question before discussing it as a group.

Here is Jen's chart with the investigation question and the goals. Note that as children discuss the goals, the word 'stuff' is replaced with 'materials' and the word 'things' with 'objects'. Jen facilitated this change by asking, "Is there a more scientific word we could use?" The children came up with the more precise language on their own. If they hadn't, she would have supplied it.

Explain that some of the things students will explore may be made of stuff that's more difficult to identify but that looking, feeling, or tapping and listening carefully, they'll learn more about what kinds of 'stuff' are used in making the things that they see everyday.

Finally, pass out the set of prepared objects to each group. Let students know that their job is to think about what each object is made of, and then sort the objects into groups according to their materials. Explain that there is more than one way to sort the objects and how they go about it is up to them.

Introduce the student notebooks

Tell students that, like scientists, they will be keeping a record of their work and their results in a notebook that they will bring to every science class. Let them know that their notebook entries can include many different kinds of science information, including drawings, writing, charts, and graphs.

Encourage students to think of their notebooks as a place to record ideas and questions, too. The distinction data and ideas will not be a simple one for young students and will require regular attention and feedback as you review their notebooks.

2. Sort objects by materials

Small Groups | 15 Mins | Notebook

This is the heart of the investigation, the place where children make their thinking about materials explicit by sorting objects into groups according to their material properties. Encourage them by saying,

- Put the things together that are made of the same stuff.
- Make as many groups as you need, and give each group a name.
- Discuss your choices with your workmates.

You will likely hear a good deal of discussion about what constitutes "sameness." Are bright metals and dull metals the same? Should the plastic spoon be grouped with the plastic bag, even though one object is rigid and one is floppy? Students may also show some uncertainty about how to group objects made from more than one material. Remain neutral on these matters, asking the students what they think.

Some students may group objects according to their use rather than their material, e.g., putting the three spoons, the paper cup, and the plastic bag together as "kitchen stuff." Agree that this is one way of grouping the objects, but ask them to try doing it another way, putting things made of the same kind of stuff together. Give them time to try different groupings.

When students are satisfied with their groupings, they should record their findings in their notebook. If they created four groups, they should use four boxes. Students should include the following:

- Give each group a name or title.
- Use drawings or words to show what objects they put in each group.

Also encourage students to record any questions or ideas they have in their notebooks.

3. Make meaning

All Class 10 Mins

Sharing the Findings

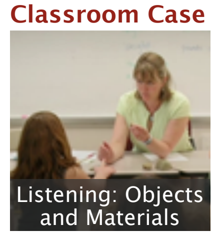
Have students meet in a discussion circle with their notebooks. Read the investigation question and ask students if they think they are getting any closer to an answer.

Using the collection of objects you set aside for group discussion, have one team show how they grouped the objects. Establish names for each group of materials, such as metal, wood, plastic, cardboard, rubber, etc.

Ask another team to say what is different about the way they grouped the objects. Ask them to explain why they put different things together.

Explain the way each team grouped these objects by materials is the information the class will use to answer the investigation question. Scientists call would call these observations “data.”

Classroom Case



Listening to Ideas about Objects and Materials

Available online at inquiryproject.terc.edu

Making Meaning

In this investigation, students’ observations are data they will use to answer the investigation question.

Purpose of the discussion

The purpose of the discussion is for students to use data to

- connect the investigation question and their data.
- reason about why there is variation in the groupings.
- make statements (claims) about the materials that objects from the classroom (things in my world) are made of and to describe the supporting evidence.

Engage students in the focus question

Ask students to look in their Notebooks and see what materials the objects they just worked with are made of.

The investigation question is:

What are things in my world made of? Based on your work with this set of objects, how would we answer this question? [metal, wood, plastic, cardboard, or fabric]

Pay special attention to the objects that cross boundaries. First are the spoons, which are made of three different materials (wood, plastic, and metal). Second are the pencil and the covered wire, which combine two or more different materials in the same object.

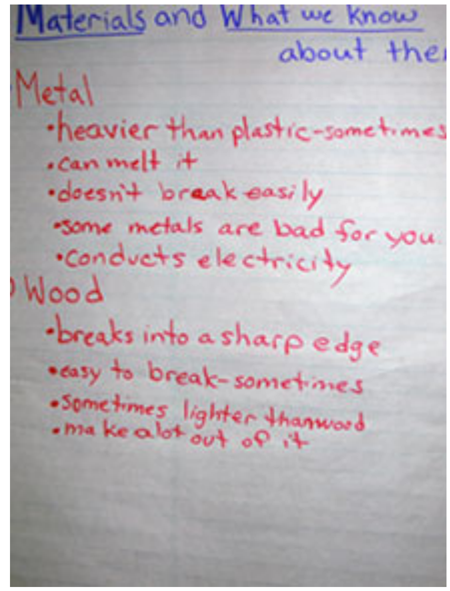
How did you decide where to put an object made of more than one material such as the covered wire or the pencil?

Ask students to think about what they know about each of the main materials: metal, wood, plastic. Ask questions like the ones listed below. Collect their ideas in a list for all to see.

How are the metal objects alike?

How do you know something is metal?

Repeat for wood and plastic. Once again, point out the investigation question. Invite children to share new insights and questions.



Extending Ideas

(As time permits) Working in pairs, invite children to look around the room and notice objects or parts of the room (e.g., the ceiling, the floor, the walls, the door, the flag) and identify the materials they are made of. Alternatively, this task can be cast as an "I Spy" game. Have pairs share their most interesting finds before ending the lesson.

4. Find a personal object

All Class 5 Mins

One teacher established a special place in the classroom for storing the personal objects and called it the "Class Museum."

Ask each child to find a small object at home, something that fits into a pocket, that they can bring to school the next day and leave there, for use during the study. The objects should not have much monetary value and might include such things as a plastic animal, a metal car, an empty purse, a key fob, or a bottle cap. You may want to refer to these objects as *personal objects*.

You can store the collection of objects together where children can easily reach them, or set them aside in a box where you can retrieve them whenever personal objects are used in the unit.

Alternatively, you can collect a set of small objects from the classroom as personal objects, for use throughout the unit.

Investigating Materials 2:
What kind of material makes an object work well?

Plan Investigating Materials 2

Feather dusters … rubber duckies … wooden boats … a tin raincoat. One of these objects doesn't sound very sensible. Why not?

In this lesson, students think about materials in terms of their *usefulness* to objects and the way those objects function. First they will consider what materials are appropriate for certain objects. Then they will brainstorm some materials that would be wildly wrong.

Together you will compile a table of objects and materials that function very well and very badly.

By the end of the investigation, students will have more experience distinguishing objects and the materials they are made of and have begun thinking about the *properties* of different materials, which is the subject of the next investigation.

Learning Goals

- to think about what materials make an object work well
- to learn to write a scientific reflection

Sequence of experiences		
1. Ask the question	All Class	15 Mins
2. Consider some materials	Small Groups	15 Mins
3. Make meaning	All Class	10 Mins
4. Write a reflection	Individual	5 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Make a table for class discussion on a whiteboard or flip chart, setting out lines for 7 objects; an example can be found in Step 1.
- 1 plastic spoon for class discussion

For each student:

- 1 personal object selected by student

1. Ask the question

All Class 15 Mins

Students have been thinking about objects and the materials they are made of. Today's question:

"What kinds of materials make an object work well?"

Some materials are better than others for a particular object; in fact some objects won't work at all if they are made of the wrong materials. Provide an example:

What are windowpanes usually made of?
(Glass, and possibly plastic)

What is it about glass and plastic that makes them good materials for windowpanes?
(Light can pass through them but they block the wind. They are transparent materials.)

Why not use wood for windowpanes? Wood is stronger and will not break as easily.
(Light can't pass through wood.)

> Have some fun with this discussion by encouraging some outlandish examples — e.g., a spoon can't be made of butter because it would melt or get eaten. This will encourage flexible thinking and introduce a wider range of material properties, which will be useful in the next lesson.

To make a useful object, you have to choose your materials carefully. Today students will investigate some objects and think about what materials work well for them. They will also think about materials that would not work well for those objects.

Complete the first row of the classroom table using the windowpane example. Next hold up a plastic spoon and ask the students what to record in the table. Use the terms row and column as you refer to places in the table.

Object	What it is made of	Other materials that might work well	Materials that would work badly
Window pane	Glass	Plastic	Wood
Spoon	Plastic	Metal, wood	Butter
(Student use)			
(Student use)			
(Student use)			
(Student use)			
(Student use)			

2. Choose and describe an object

Small Groups 15 Mins Notebook

Allow time for students to record the information about the windowpane and the spoon.

Students retrieve their personal or classroom object. They should record information for their object and at least one other object from their workgroup.

The following data is recorded in the table:

- the first column lists the name of the object.
- the second column lists the materials the object is made of.
- the third column lists any other materials that would allow the object to work well
- the fourth column lists materials that would be wrong for the object

Encourage students to share their entries with each other. Listen to how they are talking about materials, paying particular attention to whether they are distinguishing between objects and materials. Also, check to see if the students can organize information in the columns and rows of their table.

Ask a few (2-4) students with different objects to add their information to the class table.

> **Detours:** Some students may become distracted by materials that appear in an object but are not obviously related to its usefulness or function. Glitter is an example. You can refocus attention on the primary material of manufacture, but you might also point out that the extraneous materials are also “useful” — e.g., for capturing a child’s attention or making the object “pretty.”

3. Make meaning

All Class 10 Mins

Review the class table in light of the investigation question:

“What kinds of materials make an object work well?”

Purpose of the discussion

The purpose of the discussion is to heighten students’ awareness of relationships between a material, its properties, and an object’s function.

Engage students in the focus question

Based on the information in our class table, what kinds of materials make an object work well?

Use the data from class table.

This teacher has used different colored markers to clearly delineate the different rows of the table, giving a visual cue to understand the way the data is organized.

Ask students to provide a rationale for their ideas.

The material used in [object] is [what it is made of]. Does anyone else have an object that uses this material?

Do you think that this [other object] could also be made of [the alternative material] Why do you think that?

Do you agree your [other object] would not work well if it were made of [the inappropriate material] Why do you think that?

Have students defend their claims about alternative or inappropriate materials.

For example,

- "Yes, that material would also work in this object **because** it's hard [or it's strong, or it's slippery]."
- "No, that material will not work in this object **because** it's shiny [or it's too heavy or it's the wrong color]."

What would you say to a person who asks, "What kinds of materials make an object work well?"

Listen for responses that indicate students recognize that the choice of material will depend on the function of the object and the properties of the material.

Continue with this discussion, moving through the 5 objects students added to the classroom list. The purpose of this exercise is to heighten students' awareness of relationships between a material, its properties, and an object's function.

4. Write a reflection

Individual | 5 Mins | Notebook

Letter from the Engineer

You may know something about the work that scientists do. Some study the stars and planets. Some study the different plants and animals on Earth. Some study the non-living parts of Earth, such as the rocks, ice, and oceans. All scientists study the natural world to learn more about how it works. They notice changes and they try to understand why the changes are happening. They ask questions, and they often work with other scientists to try to find the answers. For example, scientists might ask, "Why did the birds that use to come here every summer stop coming? What happened? What is different now?" Scientists can spend years trying to answer their own questions. They make careful observations, they take notes, and they work to make sense of the information or data they have collected.

Scientists sometimes work with engineers, but the main job of an engineer is different than the scientist's. The main job of an engineer is to solve problems, usually to provide people with something they need or want. Engineers also ask themselves questions, but their questions are about the problems they solve. They ask, "How can we build a car that uses less gasoline?" or "How can we build a robot that will help scientists explore Mars?" Engineers also study the materials that are used to make objects. They might ask, "Will this object work better if it is made from plastic or made from wood?" or "How can we make this glass stronger, so if something hits it, it will not break?"

In your investigations you will be thinking like a scientist most of the time, but there will also be times when you will need to think like an engineer, and solve problems that will then help you to learn more about the natural world.

Look for more Letters from the Engineer. These will point out some of the times when thinking like an engineer is important.

Introduce the word reflection and explain that it means thinking seriously about something you have recently learned.

> **Language note:** Comparing reflections: Just as your reflection looks back at you from the mirror, you can look back on the day's lesson, bringing up ideas and questions about what you have learned.

Remind students of today's question: *What kind of material makes an object useful?* Students should work on the Reflection in their notebooks to complete the sentence starters:

- Something interesting I learned about objects and materials is …
- A question I have about objects and materials is …
- I wonder

You may wish to use this time to record your own reflections about how your students are currently understanding objects and materials.

Investigating Materials 3:
How are materials the same and different?

Plan Investigating Materials 3

So far the class has considered a collection of miscellaneous objects: pencils, paper cups, spoons, and so on. Now it's time to introduce some comparability into the inquiry. It's time to meet … the cubes.

Students work with a set of 8 cubes, all the same size but each made of a different material. They each carefully examine two cubes and record their observations about the materials. Then they share their findings in a class list, describing all 8 cubes.

By the end of the investigation, students will be comparing and contrasting materials in terms of their *physical properties*.

Learning Goals

- to describe materials by their physical properties
- to compare and contrast materials according to their properties

Sequence of experiences		
1. Ask the question	All Class	10 Mins
2. Investigate two cubes	Small Groups	15 Mins
3. List material properties	All Class	10 Mins
4. Make meaning	All Class	10 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Prepare a class table to record students' findings; an example is shown in Step 3.

For each group of 4:

- A full set of 8 material cubes, each cube labeled with the name of its material:
    - pine
    - oak
    - steel
    - copper
    - aluminum
    - nylon
    - PVC
    - acrylic

1. Ask the question

All Class 10 Mins Notebook

Remind students that they have been investigating some interesting *objects* and their *materials*. Recall some of the materials they examined last time: e.g. glass and plastic. Introduce today's question:

> *"How are materials the same and different?"*

Brainstorm some ideas.

> *How would you describe glass? How would you describe plastic? Which words are the same? Which are different?*
>
> *How would you describe wax? How would you describe jello? Which characteristics are the same? Which are different?*

Point out that it is sometimes difficult to compare two materials if their objects are very different. For example, erasers and truck tires are sometimes both made of rubber, but they are so different, you might never have realized that.

> *What if the objects were the same, and only the materials were different? Would it be easier or harder to compare the materials?*

Now introduce the cubes, letting the students know they will be working with these cubes for the next few weeks. Explain that the cubes are all the same size and shape, but each is made of a different material. Take up the cubes one at a time and name each material so students have a chance to hear the words spoken aloud:

- pine
- oak
- steel
- copper
- aluminum
- nylon
- PVC
- acrylic

Encourage the children to comment on these materials, perhaps naming its source, remarking on its appearance, or naming some objects they know are made of the materials.

> **Note:** See the Science Background for more information about the cube materials.

In today's investigation, we'll examine these materials scientifically — by observing their properties and recording our findings.

2. Investigate two cubes

Small Groups 15 Mins Notebook

In their first encounter with the cubes, students are given freedom to explore the materials in many different ways. Working in pairs, they closely examine two cubes at a time, both singly and side by side. Because the objects are the same, the investigation offers a *controlled comparison* of the materials, which focuses attention on their physical characteristics.

Distribute two cubes to each student. Tell each student that they will become the "expert" on their two cubes. Each group of 4 students should have a full set of 8 cubes. Working in pairs, students will examine four cubes; each student will describe two of these materials in their notebook, using the page titled, *"How are materials the same and different?"*

Encourage students to "think like scientists," using their powers of observation and their senses — but not taste -- to help them describe each material. If they need help getting started, prompt them by saying,

> **Note:** In this exercise, students may again confuse object and material. Words that describe a *material* will include information about such properties as color, texture, odor, and luster. Words that describe the *object* (in this case the cube) will include information about size, shape, and weight.

> *What color is the material? Is it shiny or dull? What else can we learn by using our eyes?*
>
> *Is the material rough or smooth, warm or cool? What else can we learn by touching it?*
>
> *Can we learn anything with the help of our ears, maybe tapping the material with a fingernail?*
>
> *Can we learn something by sniffing the material? By squeezing it?*

To help students understand the difference between describing the cube and the material, you can provide this suggestion. When I describe a material, my description will be true even if I cut off a tiny piece of the material, or if I have a huge piece of the material. If the material has a silver color and is hard, and I cut off a piece, the piece will still have a silver color and will still be hard. So that's an idea you can use to check if you are describing the material or the object.

> *Will my description still be true if I have just a tiny piece of the material, or a huge piece of the material?*

Encourage students to compare their two materials side by side, and to record the important similarities and differences in their notebooks. Also encourage students to use strong, accurate, and descriptive language. Is the material "smooth" or is it "slippery"?

As you move among the groups, listen for signs that students are beginning to think not only about *descriptions* (e.g. red, rough, and cold), but about *categories of descriptions* (e.g. color, texture, and temperature) that will help them compare and contrast the materials.

3. List material properties

All Class 10 Mins

Turning to the class table, ask all the students who are pine "experts" to meet, compare notes, and write their descriptive words in the first column. Watch for duplicates, and encourage use of words that will aid in comparison, e.g. color, odor, and texture. Occasionally ask a student to defend a description, e.g.,

> *What do you mean the acrylic is transparent? Show me.*

If students do not understand a description, or if there is disagreement about an attribute, pass the cube around for further investigation. The Investigation Question is about similarities and differences, so consensus is important. Continue through the set of materials until the table is complete.

Students will likely describe the pine cube as "light" and the copper cube as "heavy". To help students make an initial distinction between "heavy" and "heavy for size" raise the following questions:

What about a very big piece of pine? Would it be light?

What about a very small piece of copper? Would it be heavy?

So is simply being "heavy" or "light" a property of the material or of the cube?

What might be a better way to describe what is different about pine and copper?

Note: If a student describes an attribute of the cube instead of the material (e.g., sharp corners, 6 sides, or square), point out the mistake, reminding the class of the difference between an object and its material.

The pine cube is "lighter for its size", the copper is "heavier for its size". If you had two very large cubes of pine and copper, both would be heavy, but the copper would be much heavier for its size. Similarly, if you had two very small pieces of pine and copper, both would be light, but copper would still be heavier for its size. Encourage them to list heavier and lighter for size as a property of materials.

Once the table is complete, tell students that there is a special word to describe the qualities of a material; that word is *properties*. Model the use of the word:

- The properties of pine include … (read the students' list).
- The properties of oak include … (read the students' list).

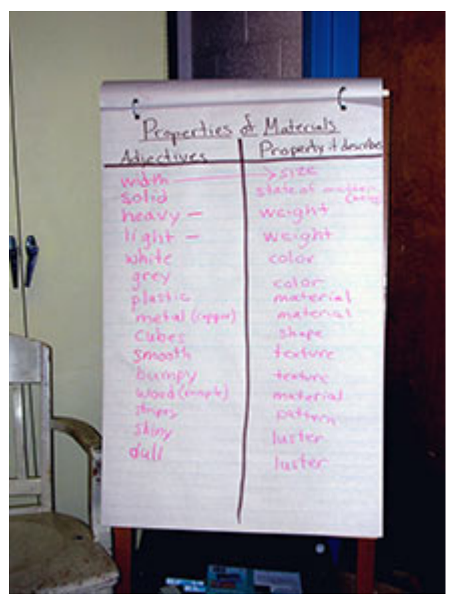
Pine	Oak	Steel	Copper	Aluminum	Nylon	PVC	Acrylic

4. Make meaning

All Class 10 Mins Notebook

Purpose of the discussion

The purpose of the discussion is to consolidate students' understanding of the terms "property," "similarity," and "difference".



Engage students in the focus question

Ask students if they think they have information to help answer the investigation question:

"How are materials the same and different?"

Suggest that students look for properties that are listed under two or more materials. Some possible findings:

- Aluminum and nylon are both smooth.
- Pine and oak both have stripes, or show the grain typical of wood, but none of the other materials do.
- Wood, pine, and aluminum are not shiny but the other materials are shiny.
- Steel feels cold but none of the other materials do.
- The materials have different colors.
- Steel seems hard when I tap on it, but pine does not.
- Acrylic is the only transparent material.
- Steel and copper are heavier for size than pine or oak.

Summarize with the following:

> *How do properties of materials help us to think about how pine and aluminum are alike and different?*

Tell students that they will continue to work with these cubes of materials for several more weeks, and that they will discover more about their properties. Make a copy of the class table on a large sheet of paper and save it so students can add more information as they go along.

Investigating Materials 4:

How can we sort cubes that are all the same size?

Plan Investigating Materials 4

Short kids … tall kids … big kids … small kids. Growing children are interested in size, and it is one of the first attributes they use to categorize objects. But how can we sort a group of objects that are all the same size?

Students are challenged to sort the 8 materials cubes at least 3 ways, each time by different properties, e.g., dull vs. shiny or heavy vs. light. Special attention is paid to groupings by weight and type of material. After comparing their results, students add some classroom objects to their groupings.

By the end of this investigation, students will be thinking about the cubes in terms of such categories as weight, color, texture, hardness, luster, and type of material.

Formative Assessment

Can students organize the properties of materials cubes into larger categories such as color or texture?

Available online at inquiryproject.terc.edu

Learning Goals

- to become familiar with the range of properties that can describe materials
- to begin organizing properties into larger categories such as color and texture

Sequence of experiences		
1. Ask the question	All Class	10 Mins
2. Sort the cubes	Small Groups	15 Mins
3. Share the data	All Class	10 Mins
4. Make meaning	Discussion	10 Mins

Materials and Preparation

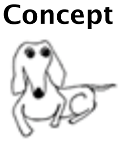
For the class:

- Post the investigation question in a place where all students can see it.
- Post the table of properties the class compiled in the last session.
- Gather 10–12 common classroom objects.
- 2 cubes that have been cut in half

For each group:

- 1 set of the material cubes

Concept Cartoon



The Materials Concept Cartoon is typically used as a formative assessment at the end of this investigation.

1. Ask the question

All Class 10 Mins

Make a connection between the last investigation and today's work. Put a set of material cubes where all students can see them. Remind students that they described the cubes' materials and made a list of ways in which those materials are alike and different.

Refer to the table students developed in the previous session. Today they will work with the same cubes. Introduce the investigation question,

> *"How can we sort cubes that are all the same size?"*

Discuss the issue that is embedded within this question: grouping objects by size is one obvious way to sort, but when all of the objects are the same size, one needs to discover other ways to sort them.

Do students need a reminder about what it means to sort things into groups? If a demonstration seems helpful, sort a small set of classroom objects by size, a property that does not apply to the cubes. Once everyone is clear about the process, tell students they will work in small groups. Each group will have its own set of eight cubes, and each group should try to find at least three different ways to sort their set of cubes. Students should record their findings in their science notebooks, on the page titled, *How can we sort cubes that are all the same size?*

2. Sort the cubes

Small Groups 15 Mins Notebook

Distribute a set of 8 cubes to each group. Challenge the groups to sort the cubes in at least 3 different ways. Remind students to record each grouping.

In the previous Materials session, students focused exclusively on the materials from which the cubes are made, and generated a list of words that describe the materials. In this session, students may sort and group the cubes in any logical way.

Likely cube groupings include the following:

- By weight: groups of heavy, medium, and light cubes; or just heavy cubes and light cubes
- By material type: groups of wood, plastic, and metal cubes
- By property: shiny cubes and dull cubes; smooth cubes and rough cubes; transparent cubes and opaque cubes

A sorting can result in the set of 8 cubes being divided into two, three, or possibly more subgroups. Encourage students to account for all the cubes in each sorting, even if it requires making a group called "None," "Other," "Miscellaneous," or "Something Else."

If students run out of ideas, suggest that they consult the class chart, looking for properties that are listed under two or more materials. Also encourage them to think about categories of descriptions — such as color, odor, texture, hardness, luster, and temperature — and that they label each of their 3 groupings with a similar "sorting word."

How are you sorting these?

What rule are you using?

What is a word for this characteristic?

Detours. Expect some category confusion. Children this age often conflate such properties as texture, luster, and opacity. They might, for example, create a grouping that sorts cubes according to whether they are "Smooth," "Shiny," or "Transparent." In this case, you might agree that the grouping sorts the cubes by some broad category like appearance, or you might move the students toward some finer discriminations by asking, e.g.,

What is the opposite of smooth? What is the opposite of shiny?

What are you really talking about here? The way the cubes look or the way that they feel?

Do these cubes belong in the same grouping? Yes? Then what is the name of the group?

3. Share the data

All Class 10 Mins

In preparation for an all class discussion, have two sets of cubes available. Record the properties students used to sort the cubes.

What is one way your group sorted the cubes? What property did you use to sort them?

Did anyone sort the cubes using a different property? What was it?

Did anyone sort the cubes by kind of material? How did you group them?

Spend a few minutes talking about the properties of the three types of materials the cubes are made of: wood, plastic, and metal.

What properties do the woods have in common? The plastics? The metals?

How did you know that copper was a metal or PVC a plastic?

4. Make meaning

Discussion 10 Mins

Purpose of the discussion

The purpose of the discussion is to elicit students' ideas about what might explain the observation that the same-sized cubes of different materials have different weights. The discussion probes their ideas about the property we call "heavy-for-size," a precursor to the concept of density.

The aim is for students to hear each other's initial ideas — not to come to a "right" answer. As they conduct more investigations in the 4th and 5th grade Inquiry curricula, they will revisit the question.

Revisit the list of properties used to sort

Restate the investigation question:

"How can we sort cubes that are all the same size?"

Remind students that all the cubes are the same size and shape but are made of different materials. Explain that one property people used to sort the cubes was of weight (e.g., light, medium, heavy) and weight is going to be the focus of the discussion.

Engage students in the focus question

These cubes are all the same size and shape but have different weights: What do you think are some possible explanations?

Some ideas you might hear are:

- The cubes are made of different materials and the materials have different weights.
- The material in metals is packed more tightly than material in wood or plastics.
- Each piece of copper weighs more than a piece of wood the same size.
- There's more air in the wood – it doesn't look all solid.
- The light cubes are hollow and the heavy ones filled with heavy things.

Supporting questions

Can you think how you might test the idea that some cubes are hollow and some are filled with other things?

- Cut the cubes in half.

What do you think the copper cube looks like on the inside?

- It looks the same all the way through.
- It has other things (heavy) things inside.

Show students the aluminum and pine cubes that are cut in half.

Note: Students commonly think wood or plastic cubes are light because they are hollow inside. While sometimes objects are hollow or filled with other materials, it is not true in this case. Explain that each cube is made of just one material and is solid all the way through.

Recap the discussion

Explain that the goal of this discussion was to hear people's ideas about why — when the materials cubes are all the same size — some materials weigh more or less than others. Summarize ideas you have heard. Point out the evidence that ruled out the idea that the light cubes could be hollow and the heavy ones filled with heavy materials. Explain that we won't try to answer the question now but it's something to continue to think about. Wrap up with the message that materials have properties such as color, luster, and a property called "heavy for size," that is, some materials are heavier for the size of the sample than others. A copper cube and a pine cube are the same size but the copper is heavier for the size than pine.

Materials Concept Cartoon


Name: ______________

What do you think about these ideas?

What would you say to:

Sam ______________

Jose ______________

Napoleon ______________

Investigating Materials

This cartoon was developed to assess students' beginning understanding of density as an intrinsic property of different materials. Students have previously investigated 8 cubes that have identical volumes, compared their weights, their properties such as color, and observed that when cubes are cut in half they look the same inside and out and are solid all the way through. This concept cartoon shows if students can use these experiences as *evidence* to evaluate different proposed *explanations* of the weight differences of the cubes. It is typically used after Investigating Materials 4, *How can we sort cubes that are all the same size?*.

Things to look for in student responses

Sam:

Sam explains that the pine cube is lighter because it is hollow, an idea initially appealing to many students because of everyday experiences with solid looking objects that are very light because they are hollow inside (e.g., boxes, soup cans). Can students see that this idea *can't explain* the weight differences of the density cubes, because they have observed a pine cube cut in half first-hand and found that it is *solid all the way through?*

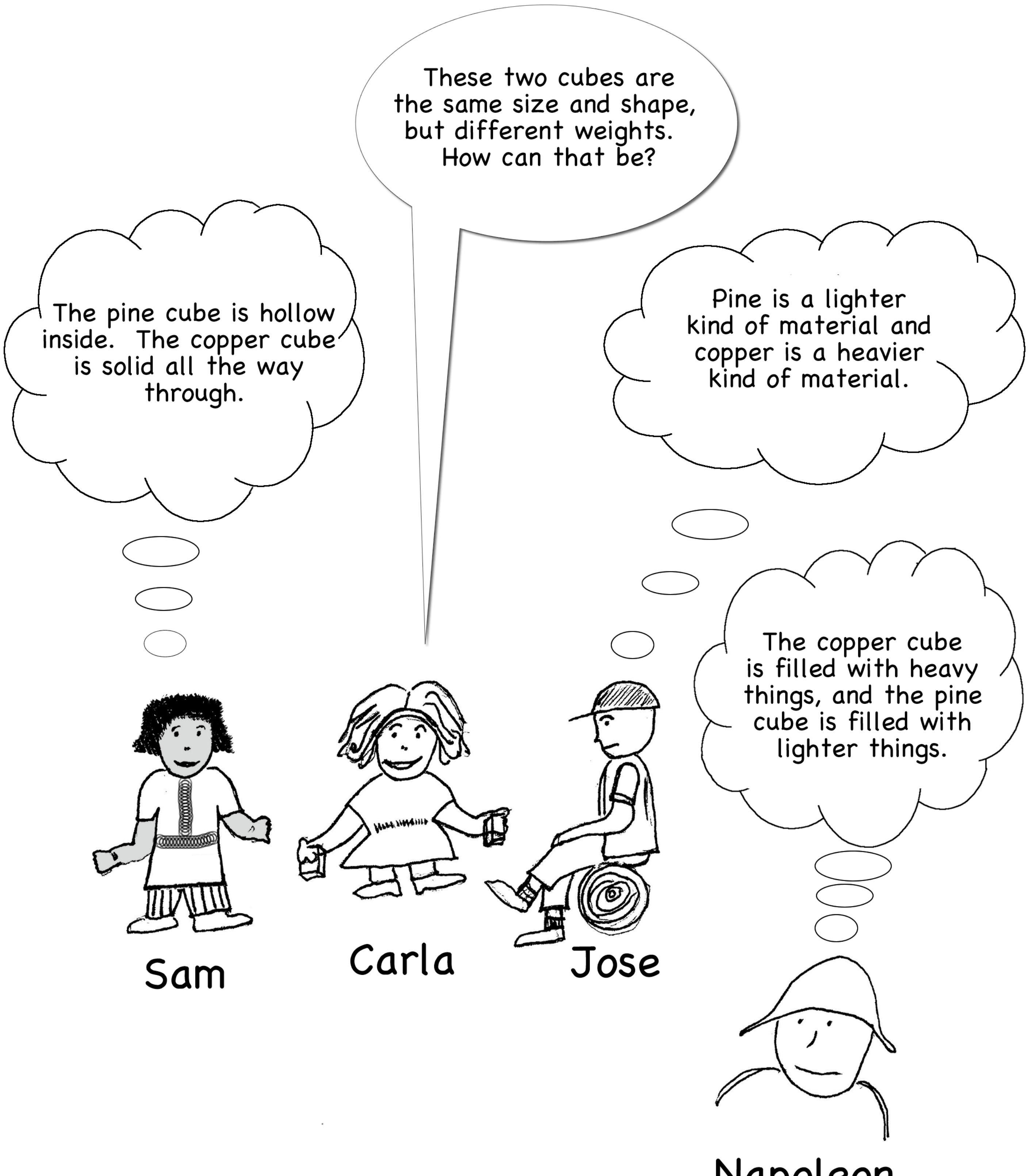
Jose:

Jose posits that the difference is due to an intrinsic difference in materials themselves (pine is a lighter kind of material than copper). Do students agree with Jose, noting that this explanation is consistent with what they have observed about the cubes?

Napoleon:

Napoleon thinks the cubes may be hollow and filled with objects of different weights, a variant on Sam's idea that is also appealing to students based on their everyday experiences. Can students use their prior experiences with the cubes to argue against this idea, noting that the pine is pine *"all the way through"* and the copper is copper *"all the way through."*

Name: ___________________



These two cubes are the same size and shape, but different weights. How can that be?
The pine cube is hollow inside. The copper cube is solid all the way through.
Pine is a lighter kind of material and copper is a heavier kind of material.
The copper cube is filled with heavy things, and the pine cube is filled with lighter things.
Sam
Carla
Jose
Napoleon

Name: ________________

What do you think about these ideas?

What would you say to:

Sam ________________________________

____

____

____

Jose ________________________________

____

____

____

Napoleon ____________________________

____

____

____

Investigating Materials 5:
How do materials help us in our classroom?

Plan Investigating Materials 5

This session provides an opportunity for children to think not just about objects and their materials but about the relationship between materials, their properties, and how those properties support students in their classroom work. This idea that students depend on the properties of materials in their everyday lives is one that they can carry with them long after this class session. Whether it's bicycles, basketballs, or lunch boxes, students can start to make more sense of the objects in their world as they develop a greater awareness of the materials they count on every day.

This session also introduces students to *observational drawing*, that is, a drawing used as data. Scientists and engineers use carefully detailed drawings as well as written notes to record their observations or share their ideas with one another. Likewise, students will include drawings as well as text to record their work and their discoveries in their notebooks.

Learning Goals

- to appreciate how the materials in our classroom help us to do our work
- to develop observational drawing skills

Sequence of experiences		
1. Discuss the challenge	All Class	15 Mins
2. Draw the pencil	Individual	15 Mins
3. Collaborate with a partner	Pairs	10 Mins
4. Consider the results	All Class	5 Mins

Materials and Preparation

For the class:

- A small bag or other container to hold the mystery object (e.g., a pencil)
- Extra copies of the “Observational Drawing” page from the Science Notebook
- A common object to use for a model drawing (e.g. a lunchbox or shoe)

For each student:

- A pencil to draw
- A lead pencil, colored pencils, or crayons to draw with

1. Discuss the challenge

All Class 15 Mins

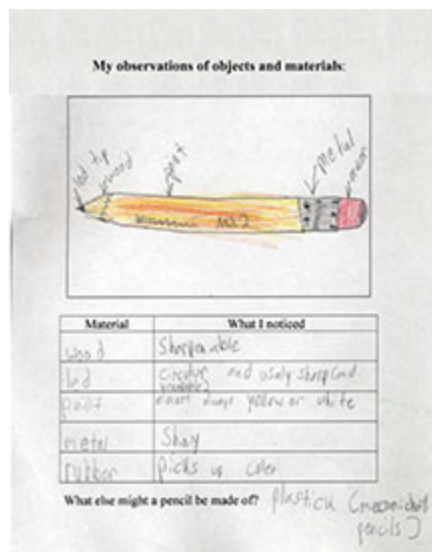
> **Note:** In this example the mystery object is a pencil, but it could be a felt tip marker or some other simple classroom object made of several materials.

To spark curiosity, introduce a mystery object hidden in a small bag. Explain that the hidden object is made of at least 5 materials, and have children guess what it is. Give clues if you need to:

- It is something you use often.
- It is probably within your reach.
- It would be hard to do your schoolwork without it.

After some guessing, reveal the pencil and describe the challenge. This object is very familiar to you. But imagine there is a third-grade class in a place far away where the students have never seen a pencil. This place is so high-tech, the students do all their schoolwork on computers — reading, writing, arithmetic, drawing — everything! You have a pen pal in that class, and she wants you to describe the pencil you use to write your letters. How are you going to do it?

Let the class brainstorm different ways to convey information about any mystery object. Talk about the advantages and disadvantages of a written description, a photograph, a video, and a drawing. Focus attention on the best way to show the pencil's materials, and the properties that make those materials useful.



Introduce the term "observational drawing." Explain that an observational drawing is a very careful drawing that scientists make to record important information so they can remember it and share it with others. Maybe they've discovered an unusual plant, or maybe they want to describe what they observed during an experiment — or maybe they want to describe a pencil to a fellow scientist in some faraway place.

Then explain that as they study objects and materials, the students will make both written notes and scientific drawings in their science notebooks — just like scientists and engineers.

> *How do you think a scientist would go about making a scientific drawing?*
>
> *What would be the first thing to do?*
>
> *How can you be sure the drawing will give detailed, accurate information?*

When you have consensus that the key to a good drawing is good observation, involve the students in identifying criteria for judging quality work. Write their ideas on the board.

Take a few minutes to model observational drawing for the class. Use a simple everyday object — maybe a lunchbox or a shoe. Speak your observations out loud and explain what you're trying to do to ensure that your drawing represents the object well. You don't need to complete the drawing, just illustrate what it means to pay attention to line, shape, and so on. Be sure to remark on parts and materials and to annotate your sketch.

Finally, let students know there is a great question to ask when you they are observing an object or making a scientific drawing of it. That question is "Why?"

> *Why does this lunchbox have padded sides?*
>
> *Why is the bottom of this shoe kind of sticky?*

2. Draw the pencil

Individual | 15 Mins | Notebook

> ***Letter from the Engineer***
> *As you work on the drawing of a pencil, you'll need to think like both a scientist and an engineer. You'll need to make careful observations about the pencil and record your observations in the drawing. Both scientists and engineers do this. Also, use notes and arrows to explain how the different materials allow a pencil to work well. This is something an engineer would do. For example, why does the pencil have a part that is wood? What problem does the wood solve? What good does it do? How does wood help the pencil to work better? What if a pencil didn't have a wooden part at all? Is there a different material you could use instead of wood that might work just as well?*

Hand out pencils as needed and have students open their notebooks to the page titled "My Observations of Objects and Materials" Remind them to observe first and then draw carefully.

Ask questions that might help students think about the relationship between the different parts of the pencil, the materials they are made of, and how the pencil works. For example,

What parts are you drawing?

Why do you think wood is a good material for the body of the pencil?

How will your pen pal know what an "eraser" is?

If we switched the wood and the rubber, would the pencil still work? Why not?

Why is the pencil painted?

Why does it say "No. 2"?

Drawing skills will be quite variable. Look for evidence that each student has identified some important parts and materials, that they relate specific properties of the materials with their usefulness, and that they are taking the exercise seriously.

3. Collaborate with a partner

Pairs | 10 Mins | Notebook

When students have completed their drawing and recording, invite them to exchange drawings with a partner of their choosing. Introduce the word *collaboration* and explain that it means "working together" and "sharing your best ideas with another person to improve each other's work." Explain that scientists frequently collaborate with other scientists to get new ideas and make joint discoveries.

Recall the criteria for successful drawings that you previously listed on the board. Ask the partners to review each other's work seriously, then to make any changes to their own drawings that would help someone understand the materials a pencil is made of and why. Perhaps say:

- You might be able to help your partner make a more scientific drawing.
- Think about how your partner paid attention to line, shape, and color.
- Will others need more notes to understand the materials the pencil is made of?

When partners are satisfied with their drawings, have them share them with another pair of students. Encourage all students to continue reviewing and revising their work until the time is up.

> **Teaching tip:** As you circulate among the groups, ask questions and focus the students' attention on parts, materials, properties, and uses. To anticipate the next unit you might ask, "How much do you think this object weighs?"

4. Consider the results

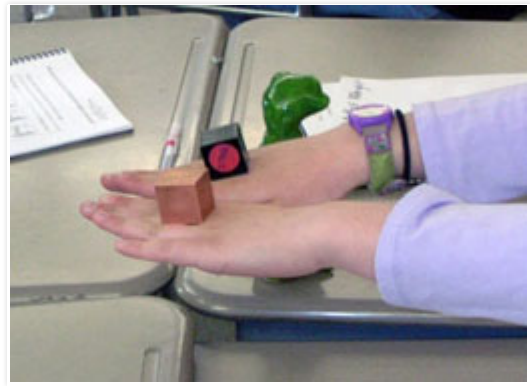
All Class 5 Mins

Invite students to take home a blank copy of the notebook page and use it as a scientist and engineer would, recording the details of a backpack, or a toaster, or any object that interests them. Have the students offer some suggestions.

The idea that students depend on the properties of materials in their everyday lives is one that they can carry with them long after this class session. Whether it's pencils, lunchboxes, bicycles, or bathtubs, students can start to make more sense of the objects in their world as they develop a greater awareness of the materials they count on every day.

Keeping it real: Over the next several months, keep up the conversation about objects, materials, properties, and uses. One way is to display all the children's scientific drawings in a special area of the classroom. Another is to keep asking the question: How do materials help us in school? As you pull down a window shade, write on an erase board, or play a game of basketball, pause long enough to ask: "What is this shade, board, or basketball made of? How does the material help make it work?"

2. Investigating Weight

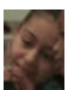


This series of investigations focuses on weight as a property of matter and makes the transition from felt weight (as perceived with their hands) to compared weight using a pan balance. Students are asked “How good are our senses at measuring weight?” They hold one cube in each hand, and use “felt weight” to determine which is heavier. They move from sorting objects into light and heavy towards ordering them from lightest to heaviest. However, they encounter a challenge when two cubes are close in weight, and soon realize that when the weight of two objects is similar, felt weight breaks down. In this way, the case for measurement is made.

Investigations:

1. How good are our senses at comparing the weights of the cubes?
2. What does a pan balance tell us about the weight order of the cubes?
3. How can we measure the weights of our cubes?
4. How much heavier is one cube than another?

The Child and the Scientist



The Child:
The Challenges in Learning about Weight

The Scientist:
Why is Weight Important?

Concept Cartoon

The Weight Concept Cartoon is typically used as a formative assessment after Investigating Weight 4

The Child's Ideas for *2. Investigating Weight*

The Challenges in Learning about Weight

> children's initial understanding of weight is limited, and very different from the understanding of scientists, as it is grounded in their perceptual experiences of weight

Children enter the classroom already knowing something about weight. The fact that objects differ in weight is salient to them, as their sensory systems respond to the pressure of objects on their hands and how much effort they have to exert to hold things or to make them move. How heavy something is not only has consequences for how easy or hard it is to pick up, but also for how it behaves with other things (e.g., light things might be blown away by the wind, whereas heavy things stay put), or how potentially dangerous it might be (e.g., heavy things cause more damage if dropped on one's foot). Further, children need to be able to unconsciously *predict* the weight of things to interact with them effectively. When they reach to pick up objects, they have to adjust their muscles for the expected weight of the object. If they are wrong, their hand may suddenly drop down or fly up, which in fact rarely happens. Thus, weight is not only important to scientists, but also to young children. In light of its importance and salience, it is not surprising that “heavy” and “light” are words that children learn very early.

At the same time, children's initial understanding of weight is limited, and very different from the understanding of scientists, as it is grounded in their perceptual experiences of weight rather than objective comparison and deeper theoretical understanding. The core of weight for children is “felt weight”—how heavy or light something feels. For example, they initially just have a few categories of weight (very heavy, heavy, light) with some small light things judged to weigh nothing at all. They also judge that two visibly different size clay balls weigh the same, because they both feel light, rather than reasoning they must weigh different amounts because they have different amounts of stuff. Weight is not yet a “conserved” quantity: they think that the weight of a clay ball changes when it is flattened into a pancake, or cut into many little pieces, because these transformations affect how heavy the object feels, rather than thinking the weight is unchanged because no clay has been added or removed. Finally, their reliance on “felt weight” encourages the conflation of weight and density. Small dense objects feel heavier than they really are because how heavy something feels depends on weight, density, perceived volume, and other variables.

The challenge is that students must use their initial concept of weight to make sense of new learning (e.g., seeing the similarity between using their two hands and the two pans of the balance scales to compare the weights of objects, forming explicit generalizations such as “big things tend to be heavy” or “plastic things tend to be light”). Then they must use the new learning to restructure their concept of weight (e.g., seeing the balance scale as a *better, more reliable* indicator of weight than their hands, using the balance scale to see that *even small additions* of material changes the weight of objects, using balance scales to measure weight in terms of some unit, thus redefining weight as an invariant property of the object that has *an exact numeric value*—this object weighs 40 paper clips—one that remains the same across transformations in which no material has been added or removed). In the process, what was initially their bedrock—their reliance on felt weight—will be called into question and what was initially less familiar or completely unknown—relations between weight and amount of matter, use of a variety of measurement tools that depend on numerical reasoning—will become their new bedrock. This kind of learning does not occur overnight or without serious reflection on and discussion of new first hand experiences—for example predicting weight orders by felt weight and then confirming or negating this order using the balance scale, asking “what if questions” to oneself, discussing reasons for observed discrepancies. This strand provides students with experiences that help them begin to make this transition, as they discover the strengths and limits of felt weight, link weight to the amount of material in an object, and learn to use the balance scale, first to compare, and then to measure weight.

—Carol L. Smith

The Scientist's Essay for *2. Investigating Weight*

Why is Weight Important?

> it's remarkable how much you can understand about the world without worrying about any properties of an object other than its weight

In the scientist's menagerie of important properties, weight is right up there at the top. (Let's get this out of the way at the beginning: What physicists really care about is "mass" and the distinction between mass and weight is near and dear to our hearts. But at the elementary school level it's not worth worrying about, and "weight" is more familiar, so I'll stick with that.) In fact when we start learning physics we treat objects as if weight were their *only* property, and it's remarkable how much you can understand about the world without worrying about any properties of an object other than its weight.

It is an object's weight, above all, that determines how it will move in response to forces — the heavier an object is, the less effect a force will have on it. The weight also determines how strongly it is attracted by, and attracts, other objects through the force of gravity. Finally, at the most basic level, the weight tells you how much stuff is in the object: how many protons and neutrons (and electrons, though they don't weigh much) make it up. A pound of lead and a pound of chicken feathers contain essentially the same number of protons and neutrons — put together in very different ways, to be sure, but still the same number.

Weight is also important because it's a *conserved* quantity — that is, the total weight of the matter in a closed system doesn't change, whatever dramatic or even violent physical and chemical processes may take place: explosions, collisions, melting, freezing — the total weight doesn't change. (Okay, that's not quite true; the famous equation $E = mc^2$ tells us that it's possible to change weight into energy and vice versa, but that becomes important only in some rare and extreme situations.) Scientists treat conserved quantities, like weight and electric charge, with special reverence. From a practical standpoint, the fact that they remain constant while other things are changing gives us a useful handle for analyzing complicated phenomena. And on a more fundamental level, the fact that they are conserved says something deep about the structure of the universe, though it's not always easy to say exactly what.

Finally, scientists care about weight because we don't fully understand it. We don't know where it comes from, and there is great excitement in the world of physics right now, because we hope that experiments at a new particle accelerator in Europe will confirm the most popular theory for the origins of weight by discovering something called the "Higgs particle". Sometimes the most basic things in science are the most mysterious.

—Roger Tobin

Investigating Weight 1:

How good are our senses at comparing the weights of the cubes?

Plan Investigating Weight 1

Children, being small, can be quite good at gauging weights. If they weren't, they'd struggle under many heavy burdens. In this investigation, students explore how well they can compare weights using only their hands.

Students first talk about evaluating weight with their senses. Working in groups, they then try to put the materials cubes in order using only the "felt weight" in their hands. When they see that different groups arrive at different orders, they consider the limitations of felt weight.

By the end of this investigation, students will see that they cannot always rely on their senses to compare weights. Some may suggest using some sort of "scale."

Formative Assessment

Can students use class data to answer the question, "How good are our senses at comparing the weight of cubes?"

Available online at inquiryproject.terc.edu

Learning Goals

- to understand the limitations of "felt weight"

Sequence of experiences		
1. Ask the question	All Class	10 Mins
2. Explore sensed weight	All Class	5 Mins
3. Order four cubes by felt weight	Pairs	10 Mins
4. Order eight cubes by felt weight	Small Groups	10 Mins
5. Make meaning	All Class	10 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Make a table on a whiteboard or flip chart to record students' orderings of the cubes; an example can be found in Step 4.
- Try ordering the cubes by felt weight yourself; it's harder than it looks.
- 3 objects that appear identical but have clearly different weights, e.g., 3 boxes of chalk containing different numbers of pieces or 3 salt shakers filled with different amounts of salt
- One pan balance

For each group:

- 1 set of cubes with the names of the materials on the cubes

1. Ask the question

All Class 10 Mins

Let students know that for the next four sessions they will be investigating weight. They will compare the weights of different things, including their materials cubes, and they will learn different ways to measure weight.

First explore students' prior experience and understanding of weight:

> *What is weight, anyway?*
>
> *What do you think is the heaviest object in this classroom? Why do you think so? How about the lightest one?*
>
> *How can we measure weight? What instruments for measuring weight have you seen or used? (Students might mention a bathroom scale, a doctor's scale with moveable weights, a hanging spring balance in the produce department, or perhaps a truck scale on the highway.)*
>
> *Are objects always measured in pounds?*

Share the investigation with the class:

> *"How good are our senses at comparing the weights of objects?"*

Tell students that their work today will help them start to answer this investigation question, but that they'll not get a complete answer until after the next class class.

> **Note:** In this session students will compare their sense of "felt weight" with that of others in the class. In the next session they will establish a weight order using a pan balance. Only then will they know how accurate their "felt weight" orderings are. Don't tell the students about the pan balance at this point, but let them know that scientists usually work for a very long time before they can answer their own questions.

2. Explore sensed weight

All Class 5 Mins

Use the three objects that appear identical but have different weights:

> *What if we wanted to order these objects by weight, from most weight to least weight, and all we could use was our sense of sight? Could we do that?*
>
> *Could hearing help us? How?*
>
> *What about touch?*

Listen for student ideas about weight and how a person can tell what something weighs. This can lead to a conversation about guessing, and how estimating differs from guessing.

> **Language note:** Make sure students understand how "order" is used in this lesson, i.e., as a verb meaning "to place things in order according to a rule." As an illustration, choose three students and ask them to "order themselves" (or "put themselves in order") by height. Ask other students to order themselves by birthdays, house numbers, and so on until you are confident everyone has a common understanding of the concept.

Next, ask two volunteers to compare the objects' weights using their hands, and to put them in order by "felt weight." When the students have finished ordering the boxes, compare the results.

> *Can we trust our eyes to compare the weights of objects?*
>
> *Can you think of a time when your eyes fooled you, and you were surprised by the feel of something's weight?*
>
> *What about touch?*

Explain that all students will have a chance to order objects by weight using just their hands and their sense of "felt weight."

3. Order four cubes by felt weight

Pairs | 10 Mins | Notebook

The investigation unfolds in two stages. In this first stage, pairs of students are challenged to order four cubes by felt weight, recording their observations in their notebooks on the page titled "How good are our senses at comparing the weights of the cubes?"

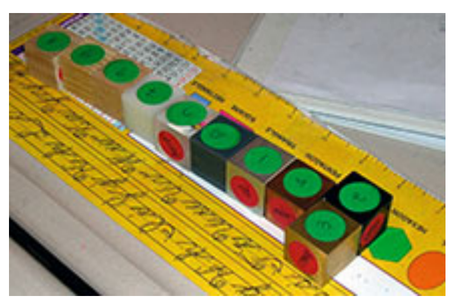
Students may handle the cubes in any way that aids comparison, perhaps holding one in each palm, or balancing one on the back of each hand, or holding them pincer-like, suspended from their fingers.

Circulate among the students as they work, offering encouragement. Perhaps they could try switching hands or closing their eyes.

The task is harder than it looks, and the students will have to work quickly, reaching consensus in about 10 minutes.

4. Order eight cubes by felt weight

Small Groups | 10 Mins | Notebook



In this second stage of the investigation, the two pairs work together to put all eight cubes in order by felt weight. When they have reached consensus, they record their ordering in their notebooks and answer the prompt at the bottom of the page, "I was surprised that … "

When the group has finished, invite one member to record their order in the class table.

Order of cubes by weight, using felt weight

Group	Least Weight → Most Weight						
1							
2							
3							
4							
5							

5. Make meaning

All Class 10 Mins

Purpose of the discussion

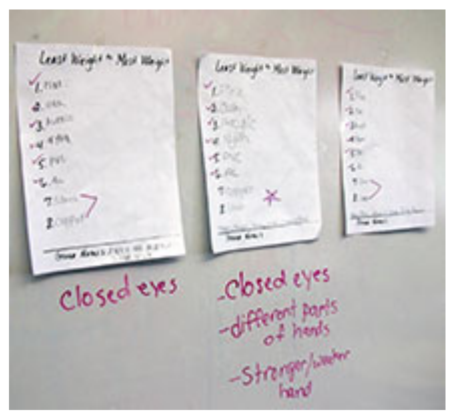
It is unlikely that every group will have placed the cubes in the same order. The investigation question, *How good are our senses at comparing the weights of cubes?* asks students to connect the investigation question with data, take a position, and identify data that support the claim.

Provide a few minutes for students to review the data table.

Engage students in the focus question

Remind students of the investigation question.

> *"How good are our senses at comparing the weights of the cubes?"*



Students will have a sense that "felt weight" is subjective–after all, there were disagreements about the orderings. They will also have seen that as the weights of objects get closer, it gets harder to distinguish them by touch. But they don't know yet how accurate their orderings might be. They are not demonstrated facts; they are *predictions*.

> *How can we know for sure?*

Let them brainstorm some ideas. If time permits, show them the pan balance and ask if anyone knows what it is or how to use it. Let them know that in the next session they will use this instrument to check the weight order of the cubes.

Be sure to save the class table for the next investigation.

Investigating Weight 2:
What does a pan balance tell us about the weight order of the cubes?

Plan Investigating Weight 2

“Maybe this order.” … “Maybe that order.” … “This is easy.” … “No, this is hard!”

Students likely encountered difficulty and disagreement,in their quest to order the cubes by felt weight. In this investigation they get help from a scientific instrument: a pan balance.

After learning how to use the balance, students compare the weights of the cubes and arrive at an objective ordering. They then compare this new ordering to the one they got before. By the end of this investigation, students will better understand the limitations of felt weight and appreciate the value of instruments for careful measuring.

Learning Goals

- to learn how to use a pan balance to compare the weights of objects
- to recognize the limitations of felt weight
- to appreciate the value of an instrument for comparing weights

Sequence of experiences		
1. Ask the question	All Class	15 Mins
2. Check the weight order**	Small Groups	15 Mins
3. Analyze the data	All Class	5 Mins
4. Make meaning	Discussion	10 Mins
5. Reflect	Individual	5 Mins

** *If this is the students’ first experience with a pan balance, they may need some extra time.*

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Post the investigation question from the previous investigation: *How good are our senses at comparing the weights of the cubes?*
- The class table from the last investigation with the “felt-weight” orderings of the cubes
- A blank table to record the pan balance ordering of cubes; an example appears in Step 2

For each group:

- 1 set of cubes with the names of the materials on the cubes
- 2 pan balances adjusted for accuracy

1. Ask the question

All Class   10 Mins

Set up a pan balance where all students can see it.

What do you suppose this is?

What could it be used for?

How do you think it might work?

> **Note:** Students may suggest that the pan balance is used to "*weigh* things." Return to that thought later, once students have seen that a pan balance can also *compare* the weights of objects without actually weighing them.

Check students' understanding by having them predict what they will observe if the objects in the two pans weigh the same. Invite a student to put a steel cube in each pan. Did students predict correctly?

Next ask students to predict what they will observe if the object in *this pan* is heavier than the object in *that pan*. Invite a student to place two different cubes in the pans. Can the students explain what happens? *Why do they think what they think?*

> ***Letter from the Engineer***
> *When you were using your senses to compare the weights of cubes, sometimes that worked well, but sometimes it was very difficult — using just your hand and your senses — to decide which cube was heavier. When the weight difference between two objects is very small, our senses may not notice the difference; they are not reliable at telling us which object is heavier. That's the kind of a problem that engineers can solve. They have designed a tool to compare the weights of objects that is more effective than our senses.*

Explore students' readiness to take the next step. Calling attention to the class table they created last session.

How can this pan balance help us check our predicted order of the cubes?

Select three cubes and have a willing student demonstrate how the pan balance can check the orderings that they arrived at by felt weight. Check to see if students understand how to use the balance in this way.

Finally, share the new investigation question:

"What does a pan balance tell us about the order of cubes?"

2. Check the weight order

Small Groups 15 Mins Notebook

Before distributing the pan balances, show students how to use the sliders to level the pans. Point out the device that indicates that the pans are level, and make sure students know how to read it. Let students know that the balances are scientific instruments and that they must handle them carefully.

Post the table from the last session alongside the new table. Have each group arrange its cubes in the weight order they decided on last time, then have them check that order using the pan balance. Ask them to record their findings both in their notebooks and in the class table.

Note: If students have not had much prior experience with a pan balance, allow time for them to explore how a balance reacts to objects in the pans and remind them to work gently. Keeping these elementary school balances well adjusted and in good working condition is important because they are not as consistent or accurate as more expensive instruments. Help students get in the habit of checking the balances prior to each use to see if any adjustments are necessary.

Order of cubes by weight, using pan balance

Group	Least Weight → Most Weight							
1								
2								
3								
4								
5								
Class Order								

Students may struggle a bit if their predicted order is proven incorrect. Encourage them to go slow, comparing one pair of cubes at a time, taking careful note of which cube is heavier — perhaps also noting whether it is “much heavier” or ”a little heavier“ — then moving on to another pair.

When all the data has been recorded, ask the class to look for discrepancies in the new, measured, orderings. Have them resolve any differences using the pan balance, then record the final result in the row labeled “Class Order.” Students should also record the final order in their notebooks.

The correct order from least weight to most weight is: Pine, Oak, Nylon, Acrylic, PVC, Aluminum, Steel, Copper.

3. Analyze the data

All Class 5 Mins

Ask students to identify instances where information (data) from the pan balance was different from the order they found using felt weight. Mark these on the class data tables.

> *When you compare the two data tables, can you find any differences in the order of the cubes by weight? Where are the differences?*

Make claims based on evidence

Encourage students to identify patterns in the data — places of agreement and places of differences — and to account for the patterns with some sort of hypothesis. They will likely find that the two orderings differ most in the areas that the pan balance showed the weights to be most similar. Students might propose, correctly, that small differences in weight are difficult to distinguish by hand.

> **Note:** The ability of our hands to sense weight differences depends not only on the relative weights of the objects but also on their actual weights. For example, our hands can tell the difference between objects weighing 20 grams and 40 grams, but probably not between objects weighing 0.2 grams and 0.4 grams, even though in both cases the weights differ by a factor of 2.
>
> Students will find that their hands are not consistently reliable for ordering objects by weight, especially when weight differences are small. The pan balance provides more accurate and consistent results, but instruments also have their limits. Inexpensive pan balances can lose effectiveness once the difference in weight between two objects drops much below 1 gram.

4. Make meaning

Discussion 10 Mins

Purpose of the discussion

This discussion will reveal what students are thinking about the question *How good are our senses at comparing weight?* and their ideas about what information a pan balance does and doesn't provide.

Remind students that today's investigation question is:

> *"What does a pan balance tell us about the weight order of the cubes?"*

Engage students in the focus question

How did the pan balance help you answer the question "How good are our senses at comparing weight?"

- The pan balance lets you compare the weight of two cubes.
- We had to make a few changes in the order we found using felt weight but not too many.
- The pan balance lets us check the order of the cubes by felt weight especially when the weights were close and it was hard to tell.
- The pan balance doesn't tell you how much more or less one cube weighs than another.

Supporting questions

What was the evidence that one cube was heavier than another?

- The heavier cube made the pan go down.

What do you think we would need if we want to know how much more one cube weighs than another?

- Counter weights such a plastic counting bears, paper clips, washers (that will be used in the next investigations), objects that weigh ounces or grams, etc.

Recap the discussion

Summarize the ideas you have heard. Point out that:

- The class now has more evidence to answer the question "*How good are our senses at measuring weight?*".
- The pan balance is a useful tool to check the relative weights of any two cubes.
- We would really like to be able to find out how much each cube weighs (this will happen in the next investigation).

5. Reflect

Individual 5 Mins Notebook

Provide time for students to complete the reflection in their notebooks.

A quick way to check your students' understanding of how the pan balance works as well as their familiarity with the cubes is to have them complete the "Checkpoint" sheet in their notebooks.

Investigating Weight 3:

How can we measure the weights of our cubes?

Plan Investigating Weight 3

Students have established the weight order of the cubes by using a pan balance to compare them with one another, but they don't yet know what the cubes weigh. Nor do they know how much more one cube weighs than another. In this investigation, they find out — but in an unconventional way.

Students use the pan balance to weigh three of the cubes using paper clips, steel washers, and plastic bears as their units of measurement. They may use these nonstandard units separately or in combination. Either way, by the end of the investigation, students will appreciate the usefulness of a single measure for weight.

Learning Goals

- to see the importance of using a rational and shared system for measuring weight

Sequence of experiences		
1. Ask the question	All Class	15 Mins
2. Weigh three cubes	Small Groups	15 Mins
3. Make meaning	All Class	15 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Make a class table on a whiteboard or flip chart for recording the weights of three cubes; an example is shown in Step 3.
- Approximately 50 grams of plastic modeling clay (for use in a demonstration)
- 1 aluminum, 1 pine, 1 oak, and 1 copper cube
- 1 pan balance

For each group:

- 1 aluminum, 1 PVC, and 1 acrylic cube
- A container with a mixture of at least 25 plastic counting bears, 40 steel washers, and 85 large paper clips
- 2 pan balances

1. Ask the question

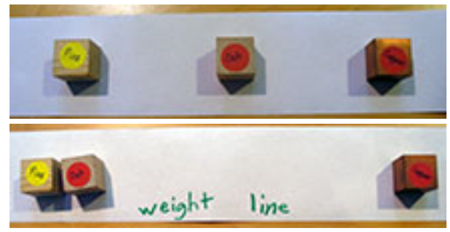
All Class 15 Mins

Gather students around the three demonstration cubes placed in weight order: pine, oak, and copper. Introduce the idea of "relative weight."

> *I put the 3 cubes in order from lightest to heaviest, but do you know more about the weights of the 3 cubes that we do not see?*
>
> *How could we arrange the cubes to show how much heavier the copper cube is than the others?*

Let students brainstorm some ideas. Create a weight line for the class, and reinforce the understanding that the weight line shows us not only the weight order; it also shows that the two wood cubes are close in weight, while the copper cube is much heavier than either of them.

> *How much heavier is the copper cube?*



Top: Pine, oak and copper cubes in order by weight.
Bottom: Pine, oak and copper cubes on the weight line ordered by "relative weight".

Let the students know that today's investigation will help them figure out how much each cube weighs, and how far apart they should be on the weight line. Introduce the investigation question:

> *"How can we measure the weights of our cubes?"*

Remind students that in the last session they used the pan balance to compare two cubes.

> *How could we use the pan balance to measure the weight of a cube?*

As they share their ideas, set up a pan balance and place the aluminum cube in one pan. Then invite a volunteer to try to weigh the cube using a piece of plastic modeling clay.

Note: Plastic modeling clay is actually not a very satisfactory material for weighing the aluminum cube; there is no clear way to describe the weight once you've finished. However, the plastic modeling clay provides a model for how to use the pan balance with a counterweight without suggesting how the students should use the specific counters (paper clips, washers, and bears) they are given.

Check to see that everyone understands how to use the pan balance in this new way. Acknowledge that the plastic modeling clay gives only a very general idea of the weight of the cube. (The aluminum cube weights about the same as a small glob of plastic modeling clay). Let students know that their measurements will be more precise because they will weigh their cubes using objects that they can count. Show students the collection of paper clips, steel washers, and plastic bears. Distribute the collection, the cubes, and the pan balances to the students. Students will weigh the three cubes in the pan balance and record their findings.

2. Weigh three cubes

Small Groups 15 Mins Notebook

This is the heart of students' investigation of weight, and it might get "messy" as they struggle to achieve comparability using the nonstandard measures.

The students face a quandary: They must weigh each cube, but their measures are mixed. Should they sort them out into three piles — paper clips, washers, and bears? Should they use the same measure for all three cubes, or should they use paper clips for one, washers for another, and bears for a third? Or should they create some sort of mixed unit, perhaps "1 small pile of stuff" or "10 mixed items"?

Offer no opinion on these matters. Rather, acknowledge the difficulty and ask, "What do you think?" and "Why?"

Check to see that students understand how to use the balance in this new way, that they handle the instrument carefully, and that they adjust the balance as needed. Also, make sure they record their weight measurements in their notebooks.

Have each group record their weights for the three cubes in the class table, making sure they identify the units.

3. Make meaning

All Class 15 Mins

Purpose of the discussion

As a result of this discussion, students recognize that they need to have a uniform or standard unit of weight in order to compare weights. If they don't do it spontaneously, they are prompted to use the class data table to support this claim.

Provide strategies for reading the data table

What can the students discover in the class data table? First ask them to look at the data in each *column*.

> *What can be observed about the weight of the aluminum cube? The PVC cube? The acrylic cube?*
>
> *Is the data difficult to interpret? Why?*

In fact, the data is likely to be very difficult to interpret because the groups had so many different units of measure to choose from.

Next ask students to look across each row.

> *Did the groups all use the same kinds of measures?*
>
> *How do the weights of the cubes compare?*
>
> *Will the data help to build a good weight line? (Probably not)*

Engage students in the focus question

Based on our class data, how can we compare the weight of our cubes?

Without consensus about the unit of measure, there can be no direct comparability. Some classes will grasp this point right away; others not at all. Work toward the understanding as best you can.

Group #	Aluminum Cube	PVC Cube	Acrylic Cube
1			
2			
3			

First see if any of the groups used a single unit of measure for all three cubes. If yes, ask what their reasoning was for doing so, and have them use their data to arrange the cubes in a weight line. If not, pursue the question inquiry-fashion:

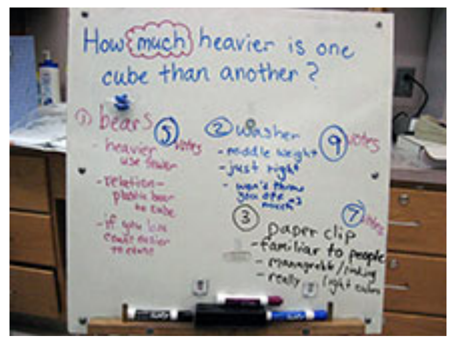
> *I wonder how we could compare these weights better. Who has an idea?*

Note: While the paper clips will provide the most accurate measurement, students must use more than 100 of them to weigh the copper cube.

If this fails, propose the strategy yourself:

> *What if we used just one of the measures to weigh all the cubes? Would that help?*

Ask the class to share ideas about which unit to use: paperclips, washers, bears — or maybe some other unit altogether. Listen to the arguments for and against each unit, and then ask the class to vote. When they have agreed on which measure to use, record the decision for the class.



Before voting on the class measure, students in this class listed the pros and cons of each counting unit.

Return to the investigation question:

> *"How can we measure the weights of our cubes?"*

Ask the class whether they think they are closer to making a good weight line.

Investigating Weight 4:
How much heavier is one cube than another?

Plan Investigating Weight 4

Paper clips … washers … counting bears … choose one!

Students weigh the cubes as well as their personal objects with everyone using the same standard unit of measurement. They record the weights (in number of paper clips, washers, or plastic bears) in a class table and place the cubes on a weight line. Students now have the data they need to address the investigation question: *How much heavier is one cube than another?* They also have an opportunity to compare two representations of the data—the table and the weight line—and to reflect on what each representation has to offer.

Formative Assessment

Do students understand that there are many weight values (possible weights) between any two numbers, for example, between 3 and 4?

Available online at inquiryproject.terc.edu

By the end of the investigation, students will start to quantify the difference in the weights of the cubes. They will also begin to appreciate the continuous nature of the weight line.

Learning Goals

- to measure and compare weights using a single measure
- to understand that there can be many different weights between any two weights

Sequence of experiences		
1. Ask the question	All Class	5 Mins
2. Weigh the cubes	Small Groups	15 Mins
3. Make meaning	All Class	15 Mins
4. Make everyday connections	Small Groups	10 Mins

Materials and Preparation

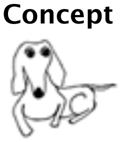
For the class:

- Post the investigation question in a place where all students can see it.
- Post the class data table for recording the weights of the cubes; an example is shown in Step 2.
- Place the class weight line with its index card label in an easily accessible place, preferably where it can remain for a while for reference.
- 180 bears or 250 metal washers or 600 jumbo paper clips
- 2 sets of cubes
- 1 index card labeled with the chosen unit of measure

For each group:

- 2 pan balances
- 4 personal objects

Concept Cartoon



The Weight Concept Cartoon is typically used as a formative assessment at the end of this investigation.

1. Ask the question

All Class 5 Mins

Recall the difficulty students had last session, when they tried to weigh the cubes using a mixture of paper clips, steel washers, and counting bears.

> *What did we decide to do this time?*
>
> *We decided to use just one measure, but which one was it?*

Once the class has agreed what the class measure is (paper clip, washer, or bear), introduce the investigation question:

> *"How much heavier is one cube than another?"*
>
> *How should we go about answering this question?*

Let the students brainstorm some ideas. There will be talk about reweighing, comparing, "counting the difference," and subtracting. Some students may suggest making a list or compiling a table or using a weight line. Entertain all such ideas, and help the class reach agreement that the task must begin with weighing all the cubes.

2. Weigh the cubes

Small Groups 15 Mins Notebook

Distribute two or three cubes (one metal and one non-metal) to each small group such that all 16 cubes will be weighed. At the same time, have the students retrieve their personal objects for weighing.

Ask a member of each group to bring one of their cubes and take enough washers (or bears or paper clips) to weigh the cube. The students can use "felt weight" to estimate how many units they will need.

Approximate Weights of Objects

Object	Weight in Paper Clips	Weight in Washers	Weight in Bears	Weight in Grams (g)
Pine	6	3	2	8
Oak	9	4–5	3–4	12
Nylon	14	7	4–5	18
Acrylic	14–15	7–8	5	19
PVC	17	8–9	5–6	22
Aluminum	34	17	11	44
Steel	98	49	32	128
Copper	112	56	37	146
Paper Clip	1			1.3
Metal Washer		1		2.6
Bear			1	4

Note: The pan balances will not give perfectly consistent results but if they have been adjusted for accuracy, differences between measurements should be less than one steel washer.

Students weigh each cube twice, putting a different student in charge each time. They record both weights in their notebooks, then agree on a final weight to record in the class data table. How they reconcile any differences in the measurements is up to them; perhaps they will weigh the cube a third time, or perhaps they will take an intermediate value, or perhaps they will consult with another group. When the table is complete, have students record the weights of all the cubes in their notebooks.

As time permits, children can weigh their personal objects and record those weights in their notebooks for comparison with the weights of the cubes.

Class Data Table

Cube	Weight
Pine	
Copper	
Oak	
etc.	

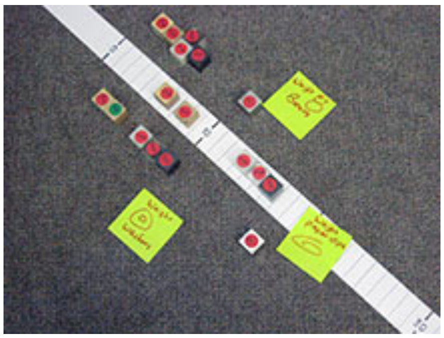
3. Make meaning

All Class 15 Mins Notebook

Purpose of the discussion

The purpose of this discuss is to consolidate learning from this investigation.

Gather students together and show them the plastic weight line. Explain that the numbers on the weight line refer to the number of measuring units that the class decided on, i.e., steel washers, or paper clips, or counting bears. Place an index card adjacent to the line labeled with the chosen unit of measure. Then invite each team to place its cubes in the appropriate place on the line.



Check students' understanding of the visual array by asking a few questions that they can answer by observation. For example,

How many cubes weigh less than 50 paper clips?

Which two cubes are closest in weight?

Looking at both the data table and the weight line, can students find the same cube in both representations? Ask several volunteers to locate different cubes both in the table and on the line.

Classroom Case

Listening to students' ideas about weight

Available online at inquiryproject.terc.edu

Note: This is the first time students will use the weight line. Are they familiar with how it is used? You may want to ask a volunteer to place the first cube on the line while others watch. Point out the weight of that cube in the table and then ask the student to find the same number on the line.

Engage students in the focus question

Our investigation question is:

How much heavier is one cube than another?

To answer this question,

What did we do?

- used uniform units of weight to weigh the cubes

Why did we do it?

- we couldn't compare weights when the units were different so we agreed to use [paper clips, washers, bears] to weigh the cubes

What did we find out?

- refer to the cubes placed on the weight line

How much heavier than the pine cube is the PVC cube?

Which cube is about twice the weight of the PVC cube?

How does each of these representations — the data table and the weight line — help you to answer these questions?

What advantages do you see with each representation?

Refer students to the page in their notebooks, and ask them to answer the four questions.

4. Make everyday connections

Small Groups 10 Mins

Invite students to add their personal objects to the weight line.

Consider the results. Are some personal objects too heavy for the line to accommodate? Can students estimate where those objects might be placed? Between which two cubes do most of the personal objects fall? Are there gaps, i.e., places where we find very few personal objects or none at all? Ask,

> *If each of you had another object to add to the line, and each of those objects weighed less than the copper cube, would there be a place on the weight line for each of those objects?*

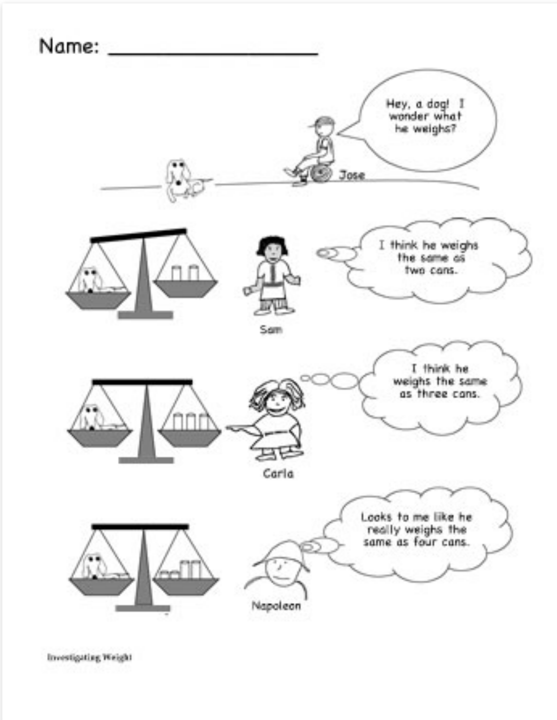
If students say "no," ask for specific examples.

> *If you have an object that weighs less than the copper cube, what could it weigh so that there would be no place for it on the line?*

Wrap up the strand by asking a couple of open-ended questions about the nature of weight.

> *What is the smallest amount of weight you can imagine an object having?*
>
> *Could two objects be so close in weight that we could not measure the difference?*
>
> *Where does the weight line end?*
>
> *What is weight, anyway?*

Weight Concept Cartoon




Name: ______________

What do you think about these ideas?

What would you say to:

Sam ______________________

Carla ______________________

Napoleon ______________________

Investigating Weight

This cartoon was developed to assess students' understanding of:

- the need for using standard units of weight
- the idea that the beam on a double pan balance is horizontal when the weights on each pan are equal

Student responses reveal whether they uncritically agree with all the characters, or have a more nuanced understanding of what makes a valid measurement. It is typically used after Investigating Weight 4, *How much heavier is one cube than another?*.

Things to look for in student responses

Sam:

Do students agree with Sam because the pan has "two cans", or do they disagree, pointing out that *the beam is not horizontal* so they can't weigh the same? Do they go even further and argue that the dog must weigh more than 2 cans because *the dog side is down*?

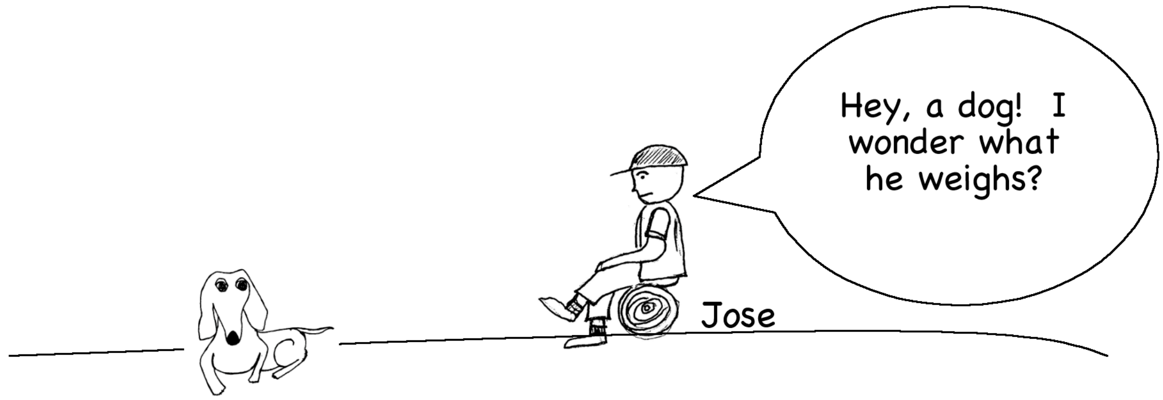
Carla:

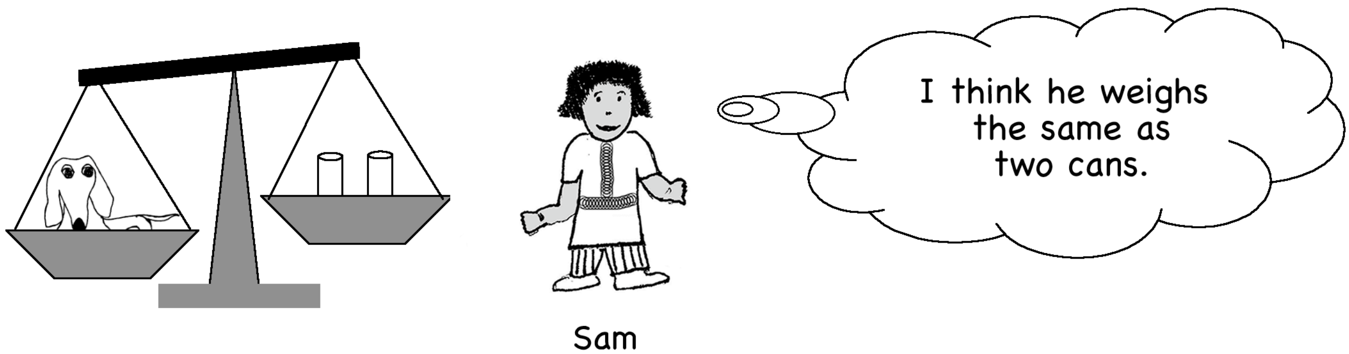
Do students not only agree with Carla, but also give good supporting reasons — for example, noting that *the beam is horizontal* and the three cans are *all the same size*?

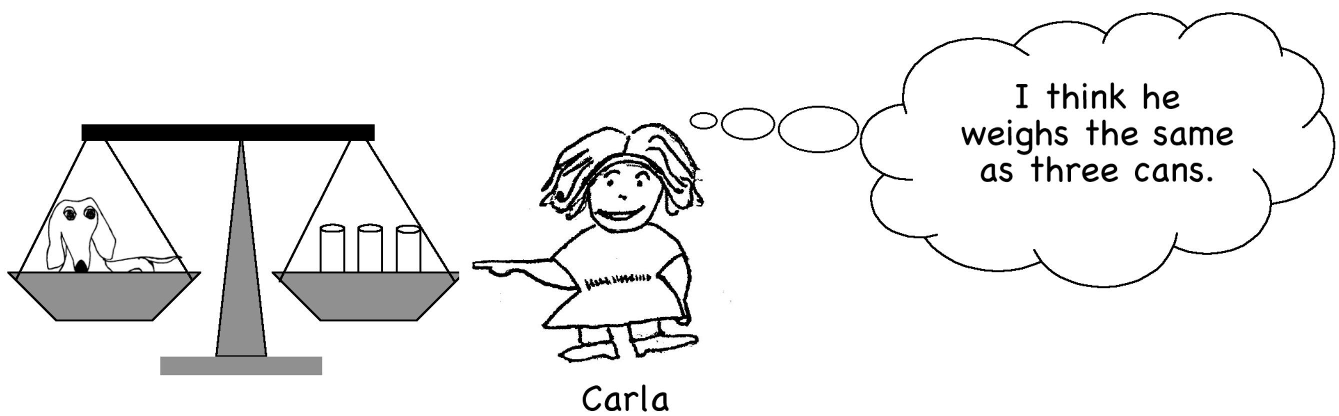
Napoleon:

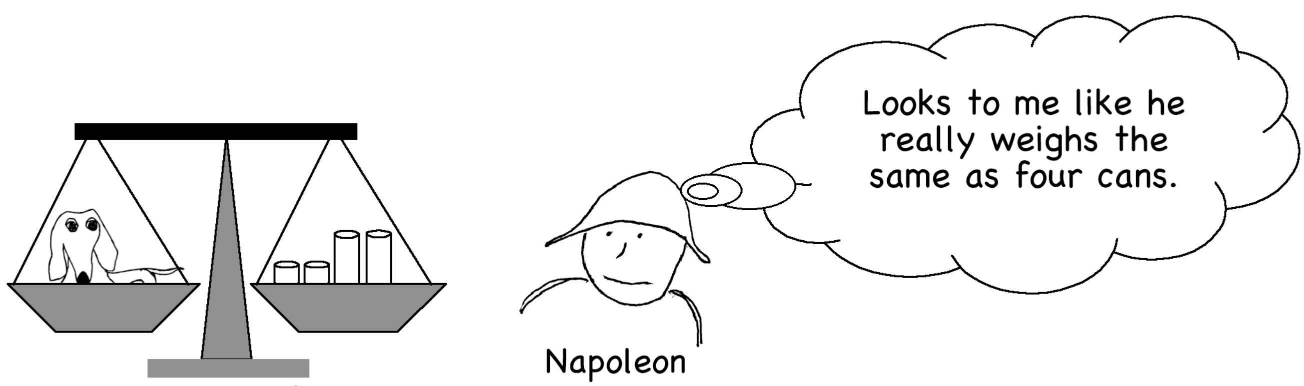
Do students agree with Napoleon because the pan has "four cans", or do they point out you can't simply add the cans together because they are not the same size? Do they go even further and say that it looks like the dog weighs three cans, because the dog balances with two large cans plus two small cans (where the two small equal one large)?

Name: ____________________


Hey, a dog! I wonder what he weighs?
Jose


I think he weighs the same as two cans.
Sam


I think he weighs the same as three cans.
Carla


Looks to me like he really weighs the same as four cans.
Napoleon

Name: ________________

What do you think about these ideas?

What would you say to:

Sam ______________________________

____

____

____

Carla ______________________________

____

____

____

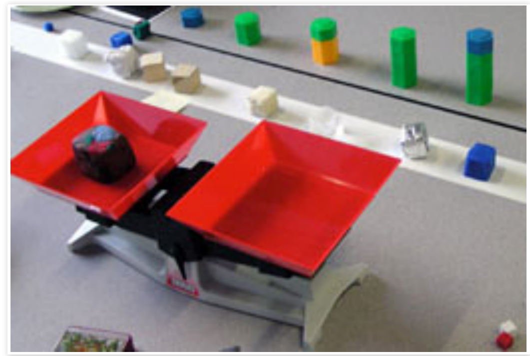
Napoleon ___________________________

____

____

____

3. Investigating Standard Measures

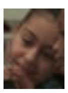


Grams are introduced as the standard unit of measure used by scientists. Students become comfortable using grams to weigh objects and are then introduced to the question of whether something could weigh less than a gram. While discovering the limitations of their tools and unit of measure, they are able to build the case that even the smallest piece of material has weight. Their investigation of standard measure culminates with a construction challenge that helps them to understand the additive nature of weight and provides evidence that some materials are heavy for their size.

Investigations:

1. How can grams help us compare weights?
2. How much do the cubes weigh in grams?
3. Do very tiny things have weight?
4. The 10-10-10-10 Challenge

The Child and the Scientist



The Child:
The Challenges in Learning about Weight Measurement

The Scientist:
Why are Standard Measures Important?

Concept Cartoon

The Standard Measures Concept Cartoon is typically used as a formative assessment after Investigating Standard Measures 3

The Child's Ideas for *3. Investigating Standard Measures*

The Challenges in Learning about Weight Measurement

> *Ultimately, learning to measure weight (and, later, volume) opens the door for discovering powerful regularities in the world.*

Learning to measure weight draws on, and brings together, children's prior understandings of both weight and numbers. In the process, children's understanding of both can be transformed.

For example, the weight of an object goes from being *felt weight* (that is, an imprecise and subjective "quantity" that can be only crudely assessed) to a precisely measured and objective quantity such as 16 grams. Further, although children can begin to measure weight drawing on only their knowledge of counting numbers (i.e., the numbers 1, 2, 3, 4 … in the count list) and the operations of addition and subtraction, precise measurement ultimately calls for them to deal with fractional units and the operations of division. Thus, learning to measure is an important context for extending and changing children's concept of numbers.

Learning to measure weight involves much more than learning a simple set of measurement procedures—it also involves developing a deeper "theory of measure." Because many of the assumptions underlying weight measurement are not obvious to children, these assumptions need to be explicitly discussed. The use of external visual representations—such as a weight line—are critical to making these assumptions public and open to discussion. The weight line integrates many elements of a theory of measure and allows students to use the line to make novel inferences.

For example, weight measurement involves identifying a unit of weight—such as one gram—and then determining how many grams it takes to balance with the object on a scale. In this way, the weight of an object is analyzed as the sum of the number of weight units; in contrast, with felt weight, there are no component units—weight is just assessed holistically. The weight line clearly represents this aspect of weight measurement by marking off "equal size" intervals that correspond to different numbers of units, and placing objects along the weight line.

Weight measurement also involves subdividing units into fractional units. As children begin to measure the weight of objects, they find that many objects have a weight somewhere "between" two weights (e.g., 10 and 11 grams). Asking children to place objects on a continuous weight line not only supports inferences about the existence of weights between two units, but also representing those weights and ordering their magnitudes visually. This in turn supports learning about fractional units, and treating them as magnitudes that can be ordered.

Weight measurement starts at 0 with increasing values along a common (continuous) dimension. In this way, measures are unlike counts, which start at 1, and everyday perceptual experience where the starting point is not clearly defined. Indeed, many small objects feel like they weigh "nothing at all," and children use the word "nothing" quite loosely (rather than the mathematical sense of 0). In everyday language, children also contrast "heavy" and "light," which may be initially conceived as opposite qualities, rather than the *same quality* (just in different amounts). Further, as children begin to map weight to number, many think that light objects may have negative weights, and confuse fractional values with negative numbers. Again, the weight line provides an anchoring context for discussing and sorting out these important issues. Where will the weight of successive halves of pieces of clay fall on the line? Will you ever get to 0?

Learning about measurement also involves developing an understanding of "measurement error"—the difference between the true value of a quantity and the value obtained from an actual measurement—as well as understanding that measuring instruments vary in sensitivity and that what measurement units are appropriate may vary for different problems. Thus, children need to be mindful about measuring—always actively thinking about what the sources of error may be, what level of precision is important for a certain kind of problem, and how to make measurements more accurately. For example, children may put a tiny piece of clay on the balance, which doesn't make the balance move. Does that mean that the piece doesn't weigh anything at all, or that the scale isn't sensitive enough to detect its weight? Students might get different values when they measure the weight of the same object at different times. Does that mean the weight of the object has really changed, or does it stem from some measurement error? If the latter, what are the sources of measurement error? Are there small random fluctuations, or some other more systematic variation, such as failure to properly calibrate the balance or putting one's thumb on one side? Without an understanding of measurement error, students may mistakenly “trust” a measurement that is obviously wrong (because it is an outlier from others). Alternatively, they might regard every difference in readings as real, instead of noticing the differences are small and in no particular direction, clustering around a central value that is likely to be the true value.

Ultimately, learning to measure weight (and, later, volume) opens the door for discovering powerful regularities in the world. Without measurement, how could children tell that the weight of an ice cube equals the weight of the water produced when it melted, or that the weight of an object made of a given material is directly proportional to its volume and that a given material can be characterized by a (constant) density?

—Carol L. Smith

The Scientist’s Essay for *3. Investigating Standard Measures*

Why are Standard Measures Important?

If you judged the practice of science from the movies, you might imagine that scientists work alone in secret laboratories, entrusting their discoveries, if at all, only to a few trusted coworkers. If that image were accurate, we would have little need for standard measures — if I want to measure lengths in units based on the length of my right pinkie finger, what difference does it make? And if I record my results in a code known only to me, who cares?

> *“Not long ago a satellite on its way to Mars was lost because the ground controllers sent instructions to the steering rockets in the wrong units, sending it hopelessly off course.”*

But that’s not how science works. The remarkable success of the scientific project is due largely to its collective nature. Results are shared, criticized, reproduced, refuted, refined, debated, sometimes rejected. An experimental result or theoretical insight, no matter how remarkable, does not become part of science until it is effectively communicated to the scientific community.

The central role of communication means that a shared language is essential, and that language extends to the units we use to communicate the results of measurements. If I report that the density of a new material is 1470.3, an experimentalist in Germany or a theorist in Japan who wants to compare her results with mine needs to know whether that value is in kilograms per cubic meter, grams per cubic centimeter, pounds per cubic foot, or something else. And if it is something else, she needs some way to convert it to other units — otherwise the measurement provides no useful information. Not long ago a satellite on its way to Mars was lost because the ground controllers sent instructions to the steering rockets in the wrong units, sending it hopelessly off course.

Even within science, standardization is far from complete. Scientists have formally agreed on the *Systeme Internationale* (SI) of units, based on meters, kilograms and seconds. But in practice, subfields develop their own units, and I sometimes have trouble reading papers even in my own field that are written by chemists, because they tend to use slightly different standard units from those preferred by physicists. It’s not a big problem, because I can always convert from their units to mine, but it impedes communication like having to look up a word in the dictionary.

—Roger Tobin

Investigating Standard Measures 1:
How can grams help us compare weights?

Plan Investigating Standard Measures 1

In their last investigations, students experimented with nonstandard units of meaure — paper clips, washers, and counting bears. In this investigation they explore — perhaps for the first time — an important unit of weight in the metric system: the *gram*.

Students weigh a variety of familiar objects in terms of grams and place those objects on the weight line. They then study the distribution of objects on the weight line, comparing size and weight. By the end of the investigation, students will be thinking of objects in terms of their gram weight. They will also be noticing that size and weight do not always correspond.

Learning Goals

- to use grams as a standard unit for measuring the weight of objects
- to think about the relationship between size and weight

Sequence of experiences		
1. Ask the question	All Class	10 Mins
2. Weigh selected objects	Small Groups	15 Mins
3. Place the objects on the weight line	All Class	10 Mins
4. Make meaning	All Class	10 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- The plastic weight line — If your weight line has been left in view since the last class, make sure the students can get to it. If not, place the weight line in an easily accessible place.
- 1 gram weight set
- 1 index card labeled “Grams”
- 1 object weighing approximately 1 pound (450 grams)
- 1 object for each student to weigh from the following:

  Objects from the kit:
  - plastic spoon
  - metal spoon
  - counting bear
  - weight line
  - wooden spoon
  - key
  - large steel washer
  - rubber eraser

  Suggested objects from the classroom:
  - roll of masking tape
  - scissors
  - baseball hat
  - 3 pencils (different lengths)
  - student notebook
  - 2 different crayons
  - roll of clear tape
  - felt tip pen
  - pen
  - stapler
  - large binder clip

For each group:

- 2 pan balances
- 1 gram weight set

For each student:

- 1 gram weight
- 1 large paper clip

1. Ask the question

All Class 10 Mins

Hand a gram weight to each child.

Is there is anything else you can think of that might weigh about the same as this piece of plastic?

How does it feel?

Tell students they are now holding a piece of plastic that weighs 1 gram. Scientists and many people in the world use grams to describe the weight of objects. Distribute large paper clips (1.2 grams) to the students to provide another example of an object that weighs about a gram. Mention that most things in the classroom weigh more than one gram, and that students will have a chance to weigh some of them later today. Students will now use grams, not steel washers, paper clips, or bears, to describe how much something weighs.

Why do you think it might be better to use grams instead of paper clips, washers, or plastic bears?
(scientists and most people in the world use grams to weigh things)

Are you more used to hearing about "pounds" when someone is talking about measuring weight?

Explain that a pound is a different unit of weight, much heavier than one gram. One pound weighs 454 grams. A gram is a fairly small unit of measure that will help them compare weights even when the difference is pretty small.

Show students the rest of the weights in the gram weight set: the 5-gram, 10-gram, and 20-gram pieces. Hand around enough weights for each student to experience the different weights. Think together about classroom objects that might weigh 5 grams, 10 grams, or 20 grams? Use a pan balance to check the guesses.

Introduce the investigation question:

"How can grams help us compare weights?"

2. Weigh selected objects

Small Groups | 15 Mins | Notebook

Note: When students used steel washers or paper clips, every item had a unit weight of 1. Using the of gram weights, students will have not just 1-gram pieces, but also 5-gram, 10-gram, and 20-gram pieces. Some students will be unfamiliar with how to take advantage of this new system. For example, to balance an object that weighs 26 grams, they may use 26 1-gram pieces instead of using a 20-gram piece, a 5-gram piece, and a 1-gram piece.

Provide each student one object from the Materials and Preparation list to weigh. Remind students to check their pan balances to see if they need adjustment and to be sure to handle them carefully.

Each student weighs an object and records the name of the object and its weight in their notebook. Students might try to estimate the weights of objects that are to be weighed.

The student balances his green pom pom with three gram weights.

3. Add objects to the weight line

All Class | 10 Mins

Note: If possible, set up the weight line in a place where it can remain for several days, perhaps against a wall.

Meet together at the weight line. Explain that the numbers will now stand for *grams* and not for steel washers, counting bears, or paper clips. Place the index card labeled “Grams” at the start of the weight line. Let students know the importance of always specifying a *unit of measure* whenever they talk about the weight of their objects.

Invite each student to add his or her object to the weight line and to say something about its weight. Make sure each child specifies the unit of measure: *grams*.

4. Make meaning

All Class | 10 Mins

Purpose of the discussion

The purpose of the discussion is to consolidate understanding that the gram is the standard unit for measuring weight and that weight can be represented on a weight line.

Set the stage for the discussion by reviewing the weight line. Check students’ understanding of using “distance from zero” to represent weight. Confirm that they understand that the weight line is continuous, i.e., that objects can fall anywhere on the line — either very close together or very far apart — and all still be part of the same line.

Engage students in the focus question

Ask the focus question:

How can grams help us compare weights?

Ask the class what they think about grams as a unit of measure.

> *Are grams easier to use than paper clips or counting bears?*
>
> *Were you able to estimate gram weights accurately?*
>
> *Would pounds work as well as grams for weighing the objects? Why or why not?*
>
> *What are the advantages of grams if we want to compare weights?*

Finally, return students' attention to the weight line and start a discussion about the relationship between size and weight.

> *Are there objects that weigh about the same but have different sizes? Can anyone explain how this can happen?*
>
> *Are there objects here that are just 1 gram different in weight? Can objects be closer than 1 gram in weight?*
>
> *What are the lightest objects on the line? How many grams do they weigh? How do the sizes of the light objects compare? Are there any surprises?*
>
> *What are the heaviest objects on the line? How many grams do they weigh? How do the sizes of the heavy objects compare? Any surprises?*

Students should now be describing their observations in terms of grams. They should begin to puzzle about the relationship between size and weight.

Provide time for students to reflect and write responses in the *Here's what I'm thinking* now section of the Notebook page.

Investigating Standard Measures 2:
How much do the cubes weigh in grams?

Plan Investigating Standard Measures 2

Students have been thinking about the cubes and their relative weights for a while. In this investigation, they see those relationships expressed in grams. While the activity is simple — just weigh and compare — students' thinking about weight becomes more sophisticated.

Students weigh the cubes in grams and place them on the weight line. As they study the array, they focus on two embedded ideas: the additive nature of weight and the continuous nature of weight. They also have another opportunity to ponder why these same-sized cubes have such different weights.

By the end of the investigation, students will be able to describe more explicitly how the weight of one cube compares to another.

Formative Assessment

Do students know the weights of the 8 cubes in grams? Do they understand why they'll use grams as the standard unit of weight?

Available online at inquiryproject.terc.edu

Learning Goals

- to determine the gram weight of the materials cubes
- to use a weight line to compare the weights of objects
- to consider the additive nature of weight
- to appreciate the continuous nature of weights

Sequence of experiences		
1. Ask the question	All Class	5 Mins
2. Weigh the cubes in grams	Small Groups	15 Mins
3. Add the cubes to the weight line	All Class	5 Mins
4. Make meaning	All Class	15 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Make a class table on a whiteboard or flip chart for recording the gram weights of the cubes; an example is shown in Step 2.
- the plastic weight line
- 1 index card labeled "Grams"
- 2 or more sets of materials cubes (each student needs one cube to weigh)
- 2 cubes that have been cut in half

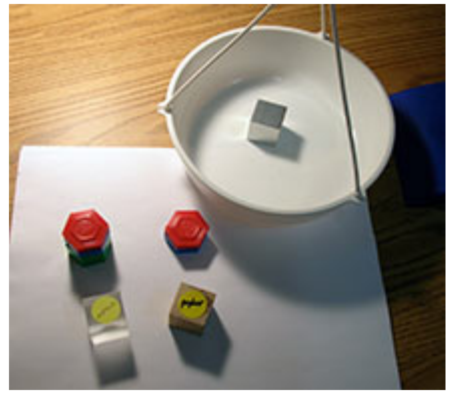
For each group:

- 1 gram weight set
- 2 pan balances

1. Ask the question

All Class 05 Mins

Show students a set of materials cubes and tell them they will weigh the cubes in grams, just as they weighed the classroom objects. Remind students that grams are the units scientists use.



This will be the students' first opportunity to discover how the weights of the cubes compare in terms of grams. Point students' attention to the investigation question:

"How much do the cubes weigh in grams?"

Let students know that more than one student will weigh each type of cube. Scientists want other scientists to try the same measurement or experiment, to see if they get the same result. This is one way that scientists learn if their work is accurate, or if they have made a mistake.

Why do scientists want other scientists to try the same measurement or experiment?

Give every student one cube to weigh. As you hand each student a cube, ask them to think about or predict how much their cube weighs in grams.

2. Measure and record the gram weights

Small Groups 15 Mins Notebook

Students work in small groups to weigh their cubes and record the weight in grams in their science notebooks. As they finish, students enter their results in the class table.

Cube Material	Weight #1 (grams)	Weight #2 (grams)	Weight #3 (grams)	Final Weight (grams)
Pine				
Oak				
Nylon				
Acrylic				
PVC				
Aluminum				
Steel				
Copper				

Table Note: Classes with more than 16 students will need part of a third set of cubes in order for every student to weigh a cube. Classes with more than 24 students will need a forth column.

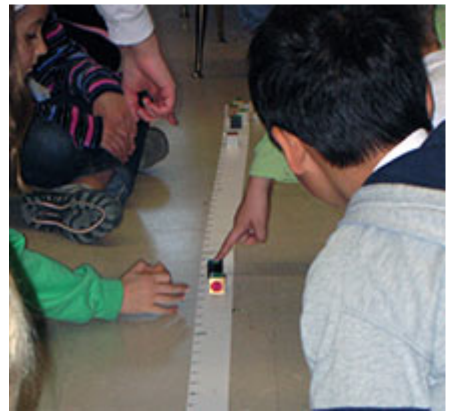
Note: See the Science Background for more information about the cube weights.

Review the results in the class table. If cubes of the same type have weight differences of a full gram or more, ask students to swap the cubes in question and weigh them one more time. Finally, have students record in their science notebooks the agreed-upon "Final Weight" of the full set of cubes.

3. Add the cubes to the weight line

All Class 5 Mins

Have students gather at the weight line with their cubes, and draw attention to the unit label: "Grams." Invite one or two students at a time to place their cubes on the line, taking their weight data from the class table or from their notebooks. Allow multiple cubes of the same material on the weight line to give everyone a sense of completion for this part of the work.



4. Make meaning

All Class 15 Mins

Purpose of the discussion

The purpose of this discussion is to bring forward the idea that weight is a property that can be increased in small or large increments.

Students can see just "how much heavier" some cubes are than others; they can even express the weight differences with some precision.

Engage students in the focus question

How much weight do I have to add to cube A to make it the same weight as cube B?

Draw students' attention to the weight difference between pairs of cubes by asking a series of questions cast in this form:

> *How much weight do I need to add to cube A to make it the same weight as cube B?*

This is a different way of asking the question, "How much heavier … ?" It avoids focusing attention on the individual weights of the cubes and instead highlights the size of the difference between them. It also emphasizes the additive nature of weight. Start by asking students about cubes that are fairly close together:

> *How much would I have to add to the acrylic cube to make it weigh the same as the PVC cube? [about 3 grams]*
>
> *How much would I have to add to the pine cube to make it weigh the same as the oak cube? [about 6 grams]*

Continue asking about pairs of cubes until the students seem to grasp that weight is a property that can be increased in small and large increments.

> **Detours:** Seeing the cubes arrayed on the weight line, students may again wonder how it is possible that objects of the same size can have such different weights. Some students may again think that the cubes are hollow or filled with some unseen material. Assure them that every cube is solid and made of the same material all the way through. Back up the claim by showing them the cubes that have been cut in half.

A Thought Experiment:

To foster understanding of the *continuous nature of the weight line*, ask students to imagine cubes made of other materials, and to say where those cubes might fit on the weight line. Consider all suggestions, both serious (e.g., a cube made of glass or brick) and more frivolous (e.g., a cube of banana, or ice cream, or cotton candy). Ask students to defend their suggested locations and to “guesstimate” the weights of their imaginary cubes in grams. By the end of the exercise, students should be clearer that every point on the weight line represents a different weight; that there are no gaps; and that a new object can be added between any two points on the line.

As you end the session, tell students that they can continue to think about and write down even more ideas for cubes that they could add to the line. Students may also reflect on the following question:

- Why use grams?

Investigating Standard Measures 3:

Do very tiny things have weight?

Plan Investigating Standard Measures 3

Snowflakes … spider silk … poppy seeds … dust. We can see that very small things occupy space, but do they also have weight?

In this investigation, students consider the weight of objects that have no perceptible weight and are too small to move the pan balance. They make the tiny objects themselves, taking an 8-gram piece of plastic modeling clay and repeatedly cutting it in halves. After each cut, they place one half on a weight line and then cut the remainder until they have a piece too small for their hands to divide further.

Formative Assessment

Do students think that very tiny things have weight?

Available online at inquiryproject.terc.edu

By then end of the investigation, students will identify some weights between zero and 1 gram and will wrestle with the idea that even teeny, tiny things have weight.

Learning Goals

- to consider whether very tiny things have weight
- to understand that there is a place on the weight line for very tiny thingss

Sequence of experiences		
1. Ask the question	All Class	10 Mins
2. Place small objects on a weight line	Small Groups	20 Mins
3. Discuss the weight of tiny things	All Class	5 Mins
4. Make meaning	Discussion	10 Mins

Materials and Preparation

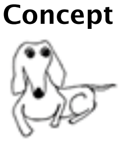
For the class:

- Post the investigation question in a place where all students can see it.
- Draw an oversized 4-gram weight line on a flip chart or whiteboard.
- 1 8-gram piece of plastic modeling clay, rolled to the thickness of a pencil

For each group:

- 2 pan balances
- 1 5-gram weight
- 4 1-gram weights
- 4 plastic knives
- 4 small plates
- 1 desktop weight line labeled from 0 to 4 grams (from notebook)
- 4 approximately 10 grams of plastic modeling clay

Concept Cartoon



The Standard Measures Concept Cartoon is typically used as a formative assessment at the end of this investigation.

1. Ask the question

All Class 10 Mins

Begin by asking students to name some of the very smallest things they can think of. Once you have a list, ask students how much they think these things weigh — or whether they have any weight at all.

Introduce the investigation question:

"Do very tiny things have weight?"

What if you can't feel any weight in your hand?

What if you can't measure any weight in the pan balance?

What if the object is lighter than 1 gram? Is there still weight?

Ask students what they think about the weight of something tiny, such as an eraser rubbing. After erasing something, do they think the tiny pieces of rubber that are left on the paper have weight? You may want to modify the posted investigation question to read, *"Do eraser rubbings and other very tiny things have weight?*

Have students exchange their ideas, but leave the questions unanswered. Let them know they will work with some tiny objects today. Show students the desktop weight lines they will use.

How is this weight line different from the one we used last time, when we displayed the weights of the cubes?

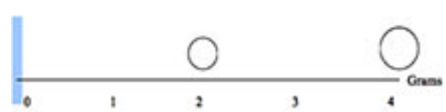
- The whole numbers are much farther apart, and the upper limit is 4 grams.

Do you think we can use this weight line to display very tiny things? Why or why not?

Detours: Some students may object to using the new weight lines. They may think that the new scale will somehow misrepresent the weights. Explain that unlike a meter stick or ruler, a weight line is not used to make measurements; it is used to display them. The spaces between gram markers can be *any size* as long as they are all the *same size*.

Show students the 8-gram piece of plastic modeling clay. Demonstrate how they might roll the plastic modeling clay, cut it in half, and place one half on the weight line in its proper place. Drawing attention to the oversized weight line you have drawn on the board, ask students, "Where will that first piece go? If you cut the remaining piece in half, where will the next piece go?"

When you have a consensus, draw circles at 4 grams and 2 grams on the class weight line. Before the class breaks into small groups, have students predict how many times they will be able to cut the plastic modeling clay in half.



Will you run out of plastic modeling clay? Will you run out of weight?

2. Place small objects on a weight line

Small Groups 20 Mins Notebook

Measure and explore

This is the heart of the investigation, where students consider the weight of ever-smaller pieces of plastic modeling clay. As the weights fall below 1 gram, students wrestle with the idea of fractional weights that approach zero on the weight line. As they cut smaller and smaller pieces, and can no longer feel the weight in their hands, they confront the question: Does weight disappear?

Students first weigh their undivided portions of plastic modeling clay in the pan balance, then work on their own to cut the material in halves, using a plastic knife. When groups have three pieces placed on their weight line. Check that the pieces are placed at the 4-gram, 2-gram, and 1-gram markers.

How much does the remaining piece weigh?

- 1 gram

Can you feel that weight in your hand?

- Yes, it feels the same as the red 1-gram weight or a large paper clip.

> **Note:** Working with plastic modeling clay. Plastic modeling clay is a good material for this exercise because it can be manipulated between cuts. If the first piece is rolled to pencil thickness, it will be easy to estimate the middle and cut it into two 4-gram pieces. You might point out that cut pieces will be easier to halve if they are first rolled into a longer, thinner pieces; or help students to discover this on their own. By working with thinner and thinner rolls, students should be able to halve the original 8 grams at least six times, possibly more.

When students cut the 1-gram piece in half, and place one piece on the weight line, check to see where it is placed.

How much does the remaining piece weigh?

- Half a gram

Can you feel that weight in your hand?

If I cut a 1/2-gram piece of plastic modeling clay into two equal parts, is there a place on the weight line to put one of the pieces? Does it still weigh something?

Continue this process one step at a time. Naming or writing the fractions below ¼ is not important to this work, but see if students develop a sense of where to place the quarter-gram, the eighth-gram, and subsequent pieces on the weight line. Do they see the pattern? *They are moving half the distance toward zero each time.*

Is the weight really disappearing? When students claim they can no longer feel the weight, suggest that they drop the piece 6 inches from one hand to the other. They should feel the piece of plastic modeling clay hit the hand. Do they agree that if they can feel something hit, it must have weight? When they can no longer feel a piece landing in a palm, ask them to drop the piece onto the back of the hand, which is more sensitive than the palm.

Do you think objects have weight, even if we can't feel the weight?

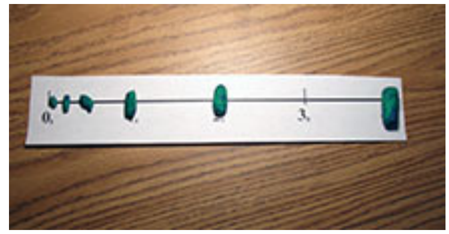
Have students sketch their weight line with the pieces of plastic modeling clay placed on it in their notebooks. Students should also record their thoughts on the weight of the plastic modeling clay pieces.

3. Discuss the weight of tiny things

All Class 5 Mins

Thought experiment

Once it becomes impractical for students to further divide the pieces of plastic modeling clay, move the exploration to a thought experiment.



If we had tiny hands and tiny knives, how many more times do you think we could cut the bits of plastic modeling clay in half?

Have students imagine cutting their smallest piece on the weight line in half again. Have them make a mark with a pencil showing where it would go on the weight line. How many times do they think they could cut the plastic modeling clay and place the pieces on the weight line?

What if the weight line were really huge, like the length of our classroom? How many pieces of plastic modeling clay could you fit between zero and 1 gram?

What if the weight line were as long as the street in front of the school? Or as long as from here to China?

Do you think there is there a place on the weight line for every teeny, tiny piece of material?

4. Make meaning

Discussion 10 Mins

Purpose of the discussion

This discussion will bring forward the idea that a piece of a material can be so small you can't "feel" any weight - and it may not even register weight on a balance scale - but it still has a place on the weight line. It has weight. You can probe what students mean when they say something "doesn't weigh anything:" do they mean they can't feel or sense any weight or that it weighs nothing and, therefore, shouldn't have a place on the weight line? This discussion can also bring forward evidence from this class that tiny things have weight: if you collect lots of tiny pieces, at some point when there are enough of them, you can "feel" their weight - this suggests that each tiny piece must contribute to the weight of the collection.

Revisit the list of properties used to sort

Return to the idea that (if you can imagine having the right tools) you could keeping cutting pieces of plastic modeling clay in half over and over again and putting these smaller and smaller pieces on the weight line.

Engage students in the focus question

Do tiny things have weight?

There's a difference between an object being so small you can't feel any weight and actually weighing nothing.

- We found that even teeny, tiny pieces have a place on the weight line (evidence from their investigation) so tiny things have weight (reasoning).
- If it's matter, even just a tiny bit, it has to have weight (reasoning).

If you gather up enough tiny pieces and add them together, the collection will weigh something, therefore, each piece weighs something.

- We started with 8 grams of plastic modeling clay, divided the pieces in half over and over again into lots of tiny pieces that didn't feel as if they had weight. If we collected all the pieces and smooshed them into a ball, the ball would weigh 8 grams.

We decided there is a place on the weight line for any piece of plastic modeling clay even if it's very, very small.

- The smaller the piece, the closer to zero on the weight line. You can't have something on zero (nothing) or on the other side of zero (you can't have negative matter).

Supporting questions

If you keep cutting the plastic modeling clay pieces in half, will you ever get to zero on the weight line?

- No, you can't have zero material, although the pieces get closer to zero on the weight line the smaller they get.

Can an object have weight if we can't feel it in our hands?

Ask students to imagine using a pencil eraser so much that the whole eraser becomes a pile of tiny eraser rubbings. If you saved every tiny piece of rubbing and piled them together, would they have the same weight as the original eraser? If each tiny rubbing had zero weight, how could there be any weight when you pile them all together? Where would that weight come from? Isn't the eraser like a collection of eraser rubbings all melted together?

If a ball of string has weight, does 1 inch of string have weight? Does half an inch? How about a quarter-inch? Do all the pieces added together have the same weight as the original ball of string? If students had cut up the whole 8 grams of plastic modeling clay into teeny, tiny pieces, would all the tiny pieces together weigh 8 grams? If not, what happened to the weight?

Recap the discussion

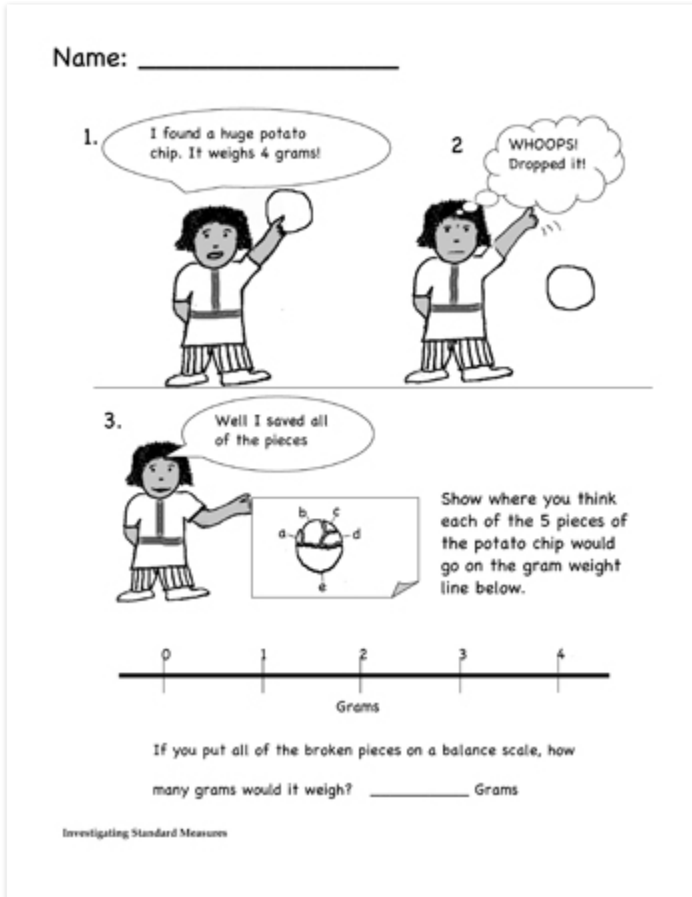
Summarize the idea that our hands (and even balance scales) are not all that good at sensing small amounts of weight or small differences in weight. Students have experienced this when they used felt weight to order the cubes. Now we are gathering evidence that objects or small bits of material can have weight even if we can't feel it. Sensing weight is limited by our hands or instruments, not by the size of the particle.

Standard Measure Concept Cartoon

This cartoon was developed to assess students' ability to:

- reason about the weight of different sized pieces of the same material
- represent the relative weights on a weight line
- understand the additive property — that weights of all the tiny pieces of an object are equal to the weight of the object

This cartoon is typically used after Investigating Standard Measures 3, *Do very tiny things have weight?*.



Things to look for in student responses

Student responses indicate how they use qualitative, non-numeric spatial information in the drawing of the broken potato chip (that shows pieces of different relative size) to make inferences about relative weights of each piece, represent those inferences on the weight line, and then reason about the weight of all the pieces added together.

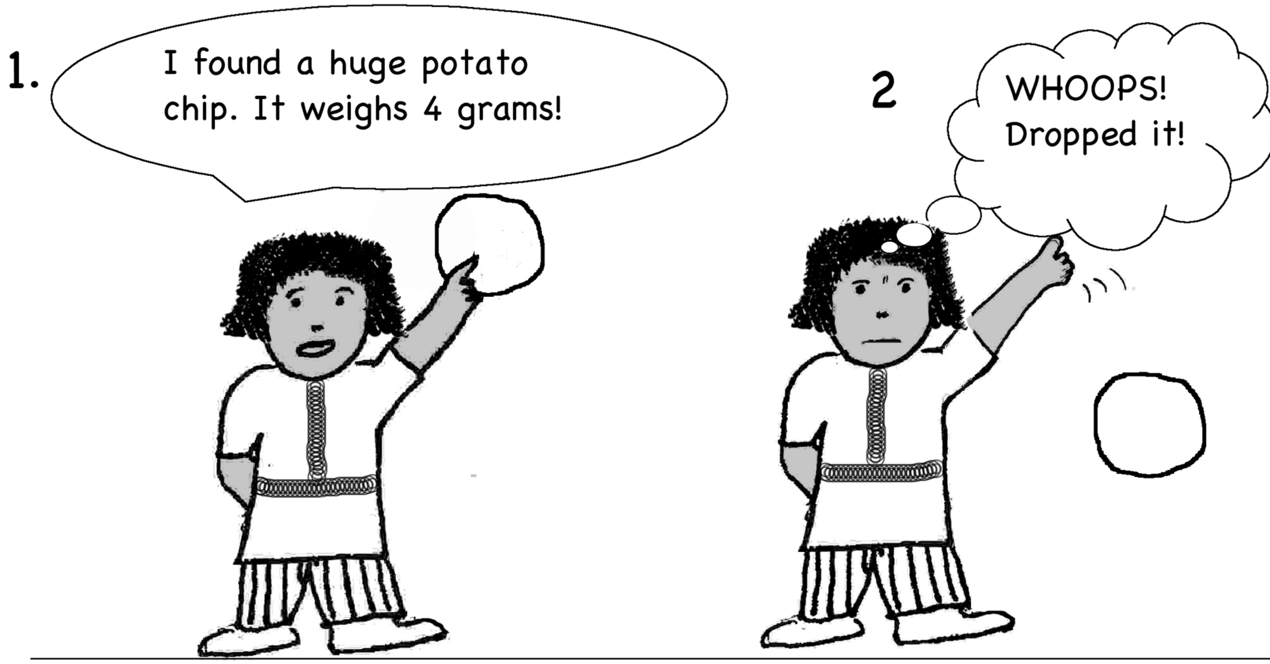
Do children use size to infer *relative order on the weight line* (inferring the following weight order: e > b > d > c > or = to a)?

Do they go further and infer the *absolute magnitude of the weights* on the line? That is, do they realize that "e" should has a weight of about 2 grams (because it is *half the size* of the whole chip which weighs 4 grams), "b" has a weight of about 1 gram (because it is about *half the siz*e of "e"), and that "d" has a weight about midway between 0 and 1 because it is *half the size* of "b"?

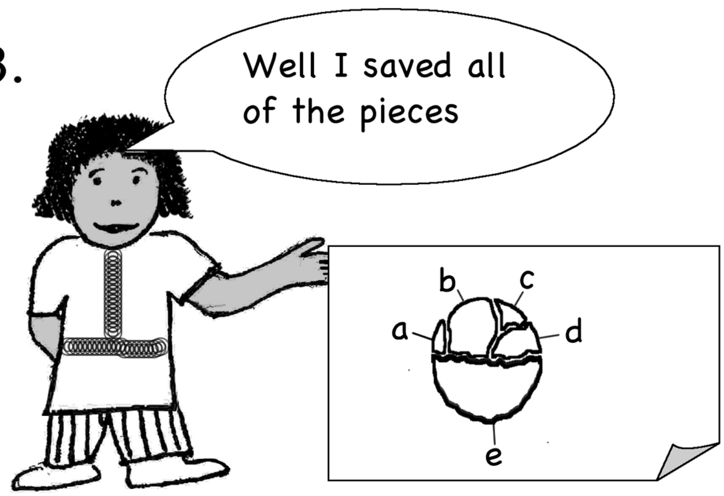
Do students realize that although a and c are very tiny pieces they still have *some weight*, or do they place them at 0 or below zero? (Note children often think tiny things weigh nothing at all or even have negative weights.)

Finally, do students realize that weight of all the broken pieces together equals the weight of the unbroken chip (4 grams)? Encouraging students to consider the additive sum of the pieces helps them see the problems with assuming tiny pieces weigh nothing at all.

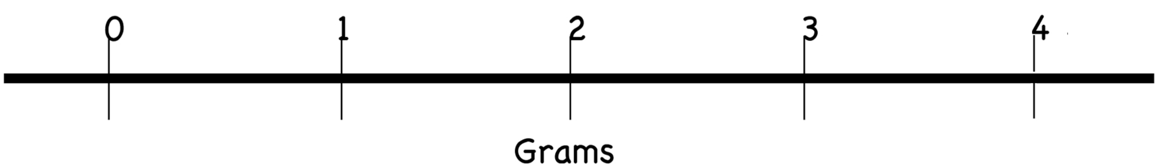
Name: ____________________



3.



Show where you think each of the 5 pieces of the potato chip would go on the gram weight line below.



If you put all of the broken pieces on a balance scale, how

many grams would it weigh? ___________ Grams

Investigating Standard Measures 4:

The 10-10-10-10 Challenge

Plan Investigating Standard Measures 4

Students are wrapping up their work with weight, so it's time for another challenge! Their mission is to create an interesting object weighing exactly 40 grams, using 10 grams each of four different materials: polystyrene (Styrofoam), aluminum foil, plastic modeling clay, and wood.

As they design and construct their objects, students practice measuring, become more familiar with grams, and see that the weight of an object depends both on size and materials. They get hands-on experience with some materials that are heavy for their size and others that are light for their size. They also use what they've learned about the additive nature of weight.

By the end of the investigation, students will have revisited many concepts and skills from the unit and will have something interesting to show for it.

Learning Goals

- to measure the weights of different materials and objects in grams
- to use the properties of materials to create an interesting new object
- to understand that the weight of an object is equal to the weights of its parts

Sequence of experiences		
1. Pose the challenge	All Class	10 Mins
2. Meet the challenge	Small Groups	25 Mins
3. Make meaning	All Class	10 Mins

Materials and Preparation

For the class:

- 1 tray or seated pan balance

For each group:

- 1 gram weight set
- 2 pan balances
- Styrofoam (more than 10 grams)
- aluminum foil (more than 10 grams)
- plastic modeling clay (more than 10 grams)
- wood stirrers (more than 10 grams)
- scissors
- plastic knives

1. Pose the challenge

All Class 10 Mins

Introduce “The 10-10-10-10 Challenge,” which is described in the science notebook. Let students know that the objects they create can be anything they can imagine, so long as they use 10 grams of each of the materials.

Introduce the materials and ask for volunteers to show, using their hands, how much space they think 10 grams of plastic modeling clay will take up. What about 10 grams of Styrofoam? What about 10 grams of aluminum foil? And 10 grams of wooden stirrers? Let them know they will soon know the answers, because their first job will be to weigh out 10 grams of each material.

> ***Letter from the Engineer***
> ***The 10-10-10-10 Design Challenge***
>
> *For this challenge you’ll need to wear more than one hat. Both your engineer and scientist hats are important because you have just four materials to work with and you’ll want to think carefully about their properties so you can make a plan and then build something that works the way you want it to. What are some things that aluminum foil can do better than Styrofoam, wood stirrers, or plasticine? What can Styrofoam do better than the other three materials? Think about each material this way, so you make good use of the materials you have to work with.*
>
> *Also, both scientists and engineers often need to do the careful weighing and measuring that you’ll need to do today.*
>
> *And you’ll want to wear your artist hat, to help you be creative and build an interesting object.*
>
> *Engineers often work together with other engineers, with scientists, and with artists and architects. The designs we develop are best when team members listen carefully and consider the ideas of others.*
>
> *This is a great problem to solve, there are many different good solutions, and I’m sure you will enjoy it.*

After reading the letter, have students brainstorm some ideas about material properties and their potential uses. Reinforce the Engineer’s advice to listen carefully to and consider the ideas of others.

Point out that each material has special properties that might be put to good use. Have students brainstorm some ideas. For example:

- the plastic modeling clay is sticky, so it might hold things together
- Styrofoam can be easily punctured to hold the stirrers in place
- the foil is shiny and can be crinkled into many different shapes
- the wooden stirrers are hard but flexible

Explain that careful weighing and measuring are important to this challenge, and so is team cooperation. Encourage the teams to brainstorm among themselves how best to use the four materials they will be given so they can to create a cool new object. Allow time for students to record their plan and design in their notebooks before distributing materials. Also encourage them to decide together how they will share the work.

2. Meet the challenge

Small Groups 25 Mins Notebook

Technical tip: Pan balances come in two types: with seated pans or with suspended pans. Seated pans are better for this investigation because the straps or chains used to suspend the pans can get in the way of larger objects that students try to weigh.

These students are finding that aluminum foil weighs a lot less than they thought.

Pass out the materials, and remind students that their first job is to measure out exactly 10 grams of each. Circulate among the teams as they do this, encouraging careful measurement, confirming the weights and answering questions.

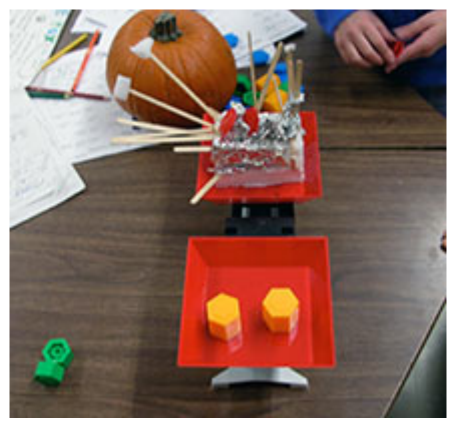
Notice whether children are comfortable breaking their 10 grams of material into a collection of smaller pieces and whether they know how much their whole object will weigh when they are done. Do they understand the additive nature of weight?

The challenge should be deliberate, exacting, cooperative, creative — and fun. Encourage imagination, play, and careful measurement.

Teaching Tip: Children may be surprised that the volume of 10 grams of material is so much greater for one material than another. Encourage them to explain why this might be so. Are they beginning to recognize the properties “light for size” and “heavy for size”?

As teams complete their constructions, have them take them to an official weighing station to determine the weight. Is it 40 grams? If not, why not? Is there material missing? (Check the floor and chairs of the work areas.) Did the students use the entire allotment of materials without first measuring out 10 grams of each? Allow students to make adjustments so that they have a construction that weighs 40 grams.

This final weigh-in can be a wonderful experience that involves careful measurement and lots of student engagement. Students return to their notebooks to describe how they’ve met the challenge.



A seated pan balance accommodates larger objects more readily than a balance with suspended pans.

3. Make meaning

All Class 10 Mins

Purpose of the discussion

The purpose of this discussion is to bring forward three big ideas about matter and weight:

- The 4 materials had the same weight but each material took up a different amount of space.
- When a 10g sample of a material was reshaped, the weight didn,Äôt change.
- The combined weight (the completed object) equaled the sum of the individual weights.

Engage students in the focus question

What did you discover about weight as you did the 10-10-10-10 challenge?

Have teams bring their objects to the group. Ask the students what all their objects have in common. Discuss the following:

- how some materials take up more space than others, even though they weigh the same
- whether the weight of the original material (10 grams) changed when it was reshaped
- whether the total weight of the object equals the sum of the parts

Can students extend this last concept for everyday objects? For example, what can they say about the weight of a wood-handled hammer *[the weight of the steel plus the weight of the wood will equal the weight of the whole hammer]*, or steel scissors with plastic handles, or a pair of metal-rimmed eyeglasses?

If possible, leave the objects in a gallery space for reference during the next set of investigations on volume.

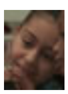
4. Investigating Volume

Students consider *how much space* different objects take up. Great care is taken to ensure that they think three-dimensionally about volume. They soon recognize the limitation of sight for comparing volumes. Students are introduced to cubic centimeters as a standard unit of measure so that they are able to measure and compare volumes. In culmination, they measure the volume of same-sized cubes and order them on a volume line. The cubes all end up in the same place on the line providing explicit evidence that objects can have the same volume, but very different weights. This again creates awareness that some objects are heavy for size—a precursor to density, a concept to be addressed formally in 5th grade.

Investigations:

1. What does it mean to take up space?
2. How can centimeter cubes help us measure volume?
3. Does changing the shape of an object change its volume?
4. How can we describe our personal objects?

The Child and the Scientist



The Child:
The Challenges in Learning about Volume

The Scientist:
Why is Volume Important?

Concept Cartoon

The Volume Concept Cartoon is typically used as a formative assessment after Investigating Volume 3

The Child's Ideas for *4. Investigating Volume*

The Challenges in Learning about Volume

> *children...do not have an intuitive concept of volume that is clearly differentiated from length, area, shape, or amount of stuff*

Size matters for young children as well as scientists. Children need to account for the size of things when picking them up (how far apart do you need to move your hands to catch the beach ball), or when putting things on shelves, in drawers, or in closets, or in selecting portions of peas. Further, some information about the relative size of objects is directly “given” in visual perception—such as when judging the relative sizes of the three bears (Papa, Mama, and Baby Bear) and their contrasting bowls, chairs, and beds.

Yet young children's concept of “object size” is quite different from scientist's concept of “volume.” Children judge how “big” something is holistically by looking—something that works reasonably well only when things are the same shape or when they are bigger in all dimensions. For most solid objects, whether something fits in a space depends more on its shape and particular dimensions than its abstract volume. Children's concept of size is quite undifferentiated; they pay attention to different features in different contexts. A big drink is different from a big dinner (probably lots of courses or different items), a big person (older, taller, heavier), or a big closet or room (how high the ceiling, how much it holds), or a big party (number of people). When children think and talk about size, they have some words to talk about size generally in a global, undifferentiated fashion (large, small, big), some words to talk about different spatial dimensions that typically focus on lengths (tall, long, wide, deep, thick, fat, skinny) and about shape (round, circle, square, heart-shape, cone-shape, star, etc.), but no words to specifically talk about volume. Although some words for specific volume measures are common in everyday life (a cup, a tablespoon, a gallon, a quart), different units are applied in different contexts and children most probably think of them as a measure of a certain amount of milk or flour, rather than a measure of its volume. In this sense, they haven't differentiated volume from amount of stuff.

Thus, the challenges in learning about volume are even more daunting than learning about weight. Whereas children enter the class with an intuitive concept of weight that they can not only name but also relate fairly easily to the balance scales, they do not have an intuitive concept of volume that is clearly differentiated from length, area, shape, or amount of stuff. Indeed, children have no way to accurately judge the volume of an object independent of its shape without having some system of formal measurement. For this reason, the very construction of a concept of volume goes hand in hand with learning to measure it. Further, there are several different senses of volume that need to be distinguished and inter-related to have a robust conception of volume. Take, for example, a can of soup; first there is the amount of space occupied by the can, second there is the amount of material (tin) the can is made of, and third, the space (volume) inside the can whether empty or full. For this reason, we choose to foreground weight and materials in our third-grade curriculum, leaving volume to be foregrounded in the fourth grade once children had a better sense of materials and how to measure weight. Nonetheless, in third grade, children begin to contrast weight and size and discuss different senses of taking up space. They also develop simple measures of the volume of objects made of solid materials (e.g. chunks of wood, clay) by building replicas with centimeter cubes, and explore how changing the shape of the object does not change its volume.

—Carol L. Smith

The Scientist's Essay for *4. Investigating Volume*

Why is Volume Important?

> *we live in a three-dimensional world and that third dimension often matters*

Size matters. But what is size? For a long-jumper or someone planning a car trip, the size that matters is a length, or distance: How far did I jump? How many miles is it from here to there? For a farmer or a real-estate agent, the important measure is area: How many acres is this field? How many square feet of floor space does the house have? Similar issues arise when you go to Home Depot: Molding or pipe is priced by the linear foot, while carpeting is priced by the square foot (area). From a mathematical standpoint the difference is dimensionality. Length or distance is a one-dimensional measurement, while area is two-dimensional.

But we live in a *three*-dimensional world and that third dimension often matters. We buy milk by the gallon and topsoil by the cubic yard, and our cars have trunk space listed in cubic feet, gas tanks measured in gallons, and engine sizes listed in cubic centimeters. These are all measures of *volume*. In other situations the important "size" is actually a weight, and for a given material (water, or flour, or aluminum, or beef) the weight is directly proportional to the volume.

In science and engineering, too, all of these measures of "size" are important, depending on the context, and we need to be skilled with all of them. For reasons perhaps known to evolutionary biologists, humans (scientists included) are pretty good at estimating, comparing, and thinking about one-dimensional measures, less adept at working in two dimensions, and largely inept at thinking in three dimensions. (Children seem to be better at three-dimensional reasoning than adults.) So the effort required to master the idea of area is greater than that required for length, and understanding volume requires even more. But that third dimension isn't going away, and we need to know how to work with it. Just be glad there aren't four.

—Roger Tobin

Investigating Volume 1:

What does it mean to take up space?

Plan Investigating Volume 1

Children are keenly aware of the size of things, especially big, bulky things that get in their way or are too unwieldy for their small bodies to handle. But the concept of *volume* is probably new to them, and it can be difficult for them to separate it from other measures that also describe an object's size (e.g., weight, height, length, area, and perimeter).

In this investigation students consider what it means to "take up space." First they brainstorm about the three dimensions of space, and then they order a set of objects by the amount of space they take up. By the end of the investigation, students will be thinking about volume as a property of objects different from weight. They will also have the beginnings of a "volume line."

Learning Goals

- to consider what it means to "take up space"
- to compare the amount of space that objects take up
- to become familiar with the term "volume"

Sequence of experiences		
1. Ask the question	All Class	15 Mins
2. Order objects by how much space they take up	Small Groups	15 Mins
3. Make meaning	All Class	15 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it
- 1 block of Styrofoam (approx. 10 cm x 10 cm x 20 cm)
- 1 pillar candle #1 (approx. 8 cm diameter x 16 cm tall)
- 1 small maple block (from 4 piece wood block set)
- Several creations from the 10-10-10-10 Challenge, if available

For each group:

- 1 small cube (cubic centimeter block)
- 1 copper cube (from the set of materials cubes)
- 1 pine cube (from the set of materials cubes)
- 1 100-gram piece of plastic modeling clay

1. Ask the question

All Class 15 Mins

Ask children to bring some of their creations from the 10-10-10-10 Challenge to the circle (if available). Recall the materials they were given to work with: 10 grams of Styrofoam, 10 grams of aluminum foil, 10 grams of wooden stirrers, and 10 grams of plastic modeling clay.

> *All four materials weighed exactly the same — 10 grams. What differences did you notice about how much of each material you were given?*

If students reply that there is "more of" some materials than others, or that the portions were "bigger," challenge them:

> *But they weigh the same. What do you mean? What is different?*

Let them struggle to describe the difference until they arrive at a consensus that some materials "take up more space," or have a "bigger shape," or "hold more air." Then pose the new investigation question:

> *"What does it mean to take up space?"*

> **Talking points:** This investigation introduces the concept of *volume*, but use the more descriptive phrase "takes up space" until the very end of the session. This phrase is more readily understood by children and it underscores the three-dimensional nature of the concept.

As the children talk about space, size and shape, make sure they are not thinking only of height and length. Listen for language that indicates they are thinking three-dimensionally, words like *back, front, top, bottom, back and forth, sideways, inside, outside, all over, all around, altogether, everywhere, the whole size, the whole shape, holding air, "like a box."*

> *How many sides does space have? How could we ever measure it?*

As the discussion winds down, tell students that, just as objects have height and weight, every object also takes up space. Put the tall pillar candle on the floor and use your hands to define the amount of space the candle takes up, moving two hands around and above the candle, to illustrate how much space this candle takes up.

> **Modeling 3-dimensional objects:** To demonstrate the meaning of *how much space* an object takes up, use both hands, in motion, to show all of the physical boundaries of an object — its top and bottom, its left and right boundaries, its front and back boundaries. By keeping your hands in motion, you focus attention on the size of the *whole* object — not only its height or length — and embody the three-dimensionality of the concept.

Next place the maple block beside the candle and move your fingers around the block in a similar way, to illustrate how much space the wood block takes up.

Finally, invite some comparisons:

> *Which object takes up more space, the candle or the block of wood?*
>
> *What about this block of Styrofoam? How does it compare?*

Leave the Styrofoam block, pillar candle, and maple block in order for later reference.

2. Order objects by space

Small Groups | 15 Mins | Notebook

This is the heart of the investigation, where students put objects in order according to volume, here expressed as "the amount of space they take up." Four objects are provided — three cubes and the plastic modeling clay — others students must imagine (three fruits).

> **Note:** The cubes are a test to see whether students can separate volume from weight. Since the cubes are the same size, they should be set side by side, but some students may still be seduced by weight. Do some think the heavier copper cube takes up more space than the pine cube? If so, recall their earlier observations about "heavy for size" and "light for size."

Give each group the three cubes and the plastic modeling clay to put in a line according to the amount of space they take up. The task will be straightforward unless the students become sidetracked by weight. Do they heft the objects to compare their weights? Do they talk about "heavier" and "lighter"? If so, remind them they are not comparing weight anymore. Tell them that they should be using their eyes and not their sense of felt weight to order things by how "much space they take up."

These students are uncertain where to put the two cubes. They are the same size, but have different weights. Where should they go?

As students finish, have them draw the four objects, in order, in their notebooks, labeling each object. If there is more than one opinion about the order, each student can record the order that seems correct.

As a group finishes ask each student to think of three pieces of fruit: one that takes up a lot of space, one that takes up very little space, and one in between. Have students draw and label the three pieces of fruit in their notebooks. This thought experiment is a higher-order exercise, requiring students to consider volume without handling the objects. If they need help, perhaps suggest that they model the fruit in the air with their hands.

3. Make meaning

All Class | 15 Mins

Purpose of the discussion

The purpose of this discussion is to consolidate students' learning about what it means to take up space and to introduce the term "volume."

Have students bring their investigation materials (the centimeter cube, the copper and pine cubes, and the 100g plastic modeling clay cube) to the discussion. Ask if any one group disagreed about how to order the cubes and plastic modeling clay. If yes, have that group to put their set of cubes in order. What does the rest of the class think? Resolve any other uncertainties in the same way.

Engage students in the focus question

Who can combine their line of 4 cubes with the order line we made earlier (with the Styrofoam, candle, and wooden block) so that there's a single line of objects ordered by the amount of space each of the objects takes up?

Take volunteers but have the whole class consult on the exercise, stopping only when you have consensus. Leave this merged order line set up in the classroom for later reference.

Ask different students to share their 'three fruits' orders with the rest of the group. If there's time, have students say where some of the fruits might go in the class order line.

Finally, return to the investigation question: *What does it mean to take up space?* Are students learning to see the three-dimensional space that an object occupies, and to compare the magnitudes of these spaces across a set of objects? Do they understand how it is different from height and length and weight? Do they think they'll be able to add new objects to this new order line?

Let students know that the amount of space an object takes up is called *volume*. Explain that "volume" can also mean an "amount of sound," like "Turn up the volume on the TV," but for this unit the class will be using "volume" to mean "amount of space."

Leave students with these questions to think about:

> *How can we describe the amount of space an object takes up?*
>
> *How in the world can we measure volume?*

Investigating Volume 2:
How can centimeter cubes help us measure volume?

Plan Investigating Volume 2

In the last session, students had a fairly easy time putting objects in volume order because the objects were dissimilar in size. In this session, the exercise becomes more difficult.

Challenged to order four wood blocks of different shape but similar volume, students struggle to "guesstimate." As it becomes clear that they need a standard unit of measure, students are given centimeter cubes to work with. By constructing replicas of the blocks with the cubes, they are able to check their estimates and put the blocks in proper volume order.

Formative Assessment
Can students use centimeter cubes to measure the volumes of 4 blocks?

Available online at inquiryproject.terc.edu

By the end of the investigation, students will have a firsthand appreciation of the need for a standard measure of volume, as well as a hands-on understanding of the unit "cubic centimeter."

Learning Goals

- to appreciate the need for a standard measure for volume
- to describe volume in cubic centimeters

Sequence of experiences		
1. Think about measuring volume	All Class	10 Mins
2. Place four blocks in a volume line	Small Groups	15 Mins
3. Explore cubic centimeters	Small Groups	5 Mins
4. Measure the volume of the blocks	Small Groups	15 Mins

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Prepare and post a class table labeled "How We Measure Things"; an example is given in Step 1.
- Prepare and post a class table labeled "Order of Blocks by Volume"; an example is given in Step 2.
- The class volume line from the previous session (with the Styrofoam, maple block, cubes, et al.)
- Label sets of 4 wooden blocks A, B, C, D; see image in Step 1.

For each group:

- 1 set of 4 wood blocks labeled A, B, C, and D, or enough blocks for each student to have 1 block
- At least 75 cubic centimeter blocks

1. Think about measuring volume

All Class 10 Mins

> **Hang on to the investigation question:** Do not refer to the investigation question until students have been introduced to the term cubic centimeter in Step 3; for now, stick with “How can we measure volume?”

Recall the work of the last session, when students thought about how much space objects take up. Draw attention to the volume line they created and pose a question:

How could we actually measure the amount of space these objects take up?

How can we measure their volume?

Have students brainstorm some answers. They may suggest measuring the height, or the weight, or filling the objects with water and then measuring the water in a measuring cup. Some of their ideas will be on the right track; others will not. As they grapple with the question, listen to what they say. Are they confusing weight and volume? Are they thinking three-dimensionally?

How We Measure Things	
Height	Centimeters Inches
Weight	Grams Pounds
How much space (VOLUME)	???

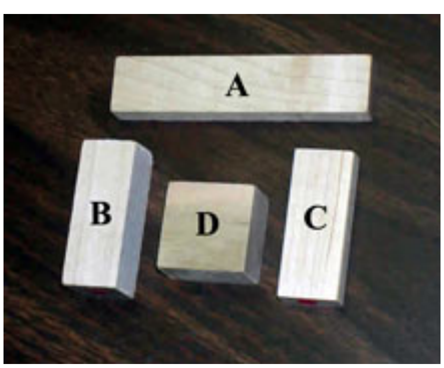
Begin to construct the table called “How We Measure Things.”

When we want to measure the height of something, what units do we use?

What about weight? Distance? Temperature?

Then fill in the last line of the table: “How much space (VOLUME),” leaving question marks in the units column. Let students know that by the end of the class, they will have an answer. But first they have a new challenge.

> **Volume formulas:** Some students may know a formula for calculating volume. Acknowledge any algorithms that are offered, but let everyone know that the class will use a different method for measuring volume.



Show students the four wooden blocks, and tell them their task is to put them in volume order. Emphasize that they must work together, that they will have to investigate the blocks very carefully, and that they must come to agreement before recording the order in their notebooks.

2. Place four blocks in a volume line

Small Groups 15 Mins Notebook

Explore and Estimate: Give students about 5 minutes to explore the blocks and to range them on a volume line from "Least volume" to "Most volume." They will quickly discover that this exercise is harder than the last one, for the volumes of the blocks are very similar.

As you circulate among the groups, ask how they are making their decisions and encourage students to think about how they might actually measure the volumes. As each group comes to consensus, have a volunteer record the order in the class table. Students should also record their order in their notebooks.

When the table is complete, ask the class to study it. Do they see any patterns? Does everyone agree which cube has the greatest volume? The least volume? Did the groups use different strategies? Where are there differences of opinion? Acknowledge that the task is hard, and let students know that it's OK to disagree because these are "guesstimates," not measurements.

Similar volumes: The volumes of three of the blocks are intentionally similar (or the same). As in Investigating Weight Investigation 1 (when the students tried to distinguish similar weights using only their senses), the point is to establish the value of having a measuring system that is precise and controlled.

Does anyone have any more ideas about how we might measure volume?

Model of table for recording the order of blocks by volume

	Least volume	Next	Next	Most volume
Group 1 Order				
Group 2 Order				
Group 3 Order				
Group 4 Order				
Group 5 Order				
Measured Order*				

** The data for "Measured Order" will be filled in during Step 4.*

The volume order of the cubes from least to most is C, A, D, B or C, D, A, B. The volume of Block C is 10 cubic centimeters. The volume of Blocks A and D is 18 cubic centimeters. The volume of Block B is 20 cubic centimeters.

3. Explore cubic centimeters

Small Groups 5 Mins

While students are still in their small groups, distribute enough centimeter cubes so that each student can hold several.

Do you think we could use these tiny cubes to help us measure volume?

How could they help use figure out the correct order of the block?

Let the students brainstorm some ideas, then introduce the unit of measure. Holding up a cube:

This is a small cube; in fact, every edge of this cube is just 1 centimeter long. The cube takes up only a small amount of space. That amount of space is called 1 cubic centimeter, and that's the unit of measurement that scientists use to measure volume.

Write "cubic centimeters" in the empty cell of the "How We Measure Things" table. Explain that two of these cubes take up 2 cubic centimeters of space (or "have a volume of 2 cubic centimeters") and five cubes have a volume of 5 cubic centimeters, and so on.

Can you think of anything that takes up about 1 cubic centimeter of space?

Where would one of these cubes go on our volume line?

Add a cube to the line, then draw attention to the investigation question:

"How can centimeter cubes help us measure volume?"

Centimeter cubes and cubic centimeters: Students may be confused at first about the difference between centimeter cubes and cubic centimeters. Centimeter cubes are the physical cubes, often made from wood or plastic; they have a dimension of one centimeter along each edge. A cubic centimeter is the amount of space that a centimeter cube takes up; it is a standard measure for volume.

If you sense confusion, ask, "Are you talking about the *object*, or are you talking about the *volume* (or, the *amount of space it takes up* or, the *unit of measure*)?"

4. Measure the volume of the blocks

Small Groups 15 Mins Notebook

Distribute the sets of centimeter cubes to each group. Have the students work together to find a way to use the cubes to determine the correct volume order of the wooden blocks.

There may be stops and starts as students reveal their misconceptions about how to measure volume. For example, they may try to measure length and width, or they may surround the perimeter of a block with the centimeter cubes.

Measure: The most successful strategy is to use the cubes to replicate a block, and then count the cubes to determine the volume. If one group discovers this strategy, they can share it with the class. Make sure each student in a group measures the volume of at least one block, using the replication strategy. Then have the group establish the volume order of the blocks based on these measurements.

By building a replica of Block Busing centimeter cubes, students can see that the volume of the block is 20 cubic centimeters.

After everyone has recorded the measured order their notebook, ask one student to enter the “Measured Order” in the bottom row of the class table. Make sure the entry includes the unit of measure: cubic centimeters.

Does everyone agree on the measured volumes? How do the measurements compare to the “guesstimates”? Do students see how the opportunity to measure volume allows them to order the blocks even when the differences are very small?

Finally, ask students to add one set of the blocks to the volume order line.

Investigating Volume 3:

Does changing the shape of an object change its volume?

Plan Investigating Volume 3

What if you had a bucket of sand, and you made a sandcastle with it. What would happen if you scooped up all that sand and made a sand dragon instead? Would the dragon have the same volume as the castle?

In this investigation, students grapple with the idea that volume can remain constant when an object changes its shape. First they arrange eight wooden cubes into different shapes and determine that the volumes of the different objects are the same. Then they repeat the activity using plastic modeling clay.

As they squeeze and poke the plastic modeling clay into irregular shapes — and can no longer count the cubes — they are left to wonder: Same volume or different?

Formative Assessment

Do students understand that the volume of 8cc of plastic modeling clay stays the same even if you change the shape?

Available online at inquiryproject.terc.edu

Learning Goals

- to consider whether changing the shape of an object also changes its volume

Sequence of experiences		
1. Ask the question	Small Groups	15 Mins
2. Explore shape and volume with wooden cubes	Small Groups	10 Mins
3. Explore shape and volume with plastic modeling clay cubes	Small Groups	20 Mins
4. Make meaning	All Class	10 Mins

Materials and Preparation

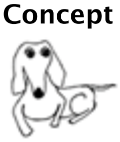
For the class:

- Post the investigation question in a place where all students can see it
- Class volume line from the previous sessions

For each student:

- 1 plastic knife
- 1 small plate
- 8 centimeter cubes
- Approximately 10 cubic centimeters of plastic modeling clay

Concept Cartoon



The Volume Concept Cartoon is typically used as a formative assessment at the end of this investigation.

1. Ask the question

Small Groups 15 Mins

Drawing attention to the objects arrayed on the class volume line:

How is volume different from shape?

It's a tricky distinction, and students may struggle with it. What responses do they have? Encourage different formulations until you reach a consensus like this:

Shape describes what an object looks like, or how it is arranged. Volume describes how much space it takes up.

Check for understanding:

Can two objects have the same shape but have different volumes?

- Yes, for example a small cube and a large cube.

Once the class is clear about the distinction between shape and volume, introduce the investigation question:

"Does changing the shape of an object change its volume?"

> **What about compressible materials?** This investigation deals with incompressible materials like wooden blocks. Simply rearranging the blocks into different shapes will not change their volumes. Compressible materials behave differently. For example, when you squeeze a slice of Wonder Bread, it loses volume.

Help them with the inquiry by presenting some scenarios:

Say you made a robot out of 300 Lego pieces. What if you took the robot apart and made a spaceship instead, using all the Legos. Do you think the robot and the spaceship have different volumes?

What if you and your best friend each have a liter of milk. If you pour all your milk into a big jar, and your friend pours all his milk into 16 glasses, who has more milk?

Say you had a wall made of bricks. If you tore it down and built a whole different wall, using all the same bricks, would the new wall have the same volume as the old wall? Let's find out.

2. Explore shape and volume with wooden cubes

Small Groups 10 Mins

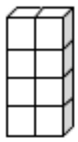


Fig. A

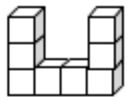


Fig. B

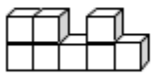


Fig. C

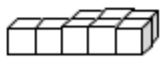


Fig. D

Explore: Start the exploration by distributing eight centimeter cubes to each student. Do they remember that each cube has a volume of 1 cubic centimeter? Have each student construct a rectangle-shaped building that is four cubes (or four “stories”) tall and two cubes wide (see Figure A). When everyone has finished, ask a volunteer to describe the volume. If necessary, remind the class that the volume can be found by counting the cubes.

Predict: Now ask the students to predict what the volume will be if they rearrange the eight cubes into a different shape. They should record their predictions in their notebooks.

Explore: At each table, have one student construct a new four-story building, one construct a three-story building, one construct a two-story building, and one construct a one-story building (see Figures B, C, and D for examples); each building must use all eight cubes. Students should record the volume of their new building in their notebooks. Ask students to report on the volume of their new buildings.

Is there agreement that the volume remains the same, i.e., 8 cubic centimeters, or are there different opinions? Ask students to show you the method they used for determining the new volume. Is everyone focused on volume, or are some thinking about area, perimeter, length, or height? Drawing attention again to the investigation question:

> *“When using wooden centimeter cubes, does changing the shape of an object change its volume?”*

3. Explore shape and volume with plastic modeling cla

Small Groups 20 Mins

Students continue to explore the investigation question, this time using a different material: plastic modeling clay.

Give each student approximately 10 cubic centimeters of plastic modeling clay. Have students use their plastic knife to help them shape the plastic modeling clay into eight individual centimeter cubes. They can use the wooden cubes as models.

As they finish, have students return the excess plastic modeling clay to a central location.

Check understanding:

> *How much plastic modeling clay do you have?*

- 8 centimeter cubes = 8 cubic centimeters

Tell students that they now have a new challenge: To create a new building, this time using their plastic modeling clay cubes. There are just two rules:

1. They must use all eight cubes
2. They must keep four of the cubes in cube shape, but they can change the shape of the other four cubes in any way they please.

Point out that since the plastic modeling clay cubes stick together — and can be squeezed and poked — students will be able to make shapes that were not possible when they were using the wooden cubes.

As they finish, have students place their constructions on a large piece of paper in the class meeting area and gather there for discussion.

4. Make meaning

All Class 10 Mins

Purpose of the discussion

This discussion will bring forward students' ideas about volume. When 8 cubic centimeters of plastic modeling clasy are reshaped, does the volume stay the same or change? You may want to review The Challenges of Learning About Volume. It's easy to underestimate the challenges presented as students begin to learn about volume. In this discussion, listen carefully to students' ideas. Provide plenty of "wait time" so you and your students can make sense of the conversation. In this discussion, encourage students to support their position (no, the volume doesn't change or yes, it does) with evidence and reasoning.

This class built 10 cubic centimeter shapes.

Deep understanding of volume develops over time. If a student's understanding of volume seems fragile at this point in time, remember that this concept will be revisited and is a focus of the 4th grade curriculum.

Revisit the activities the students have just completed

Remind students where they began: making different arrangements with their 8 centimeter cubes and deciding that the volume was always 8 cubic centimeters — they hadn't added any cubes or taken any away. Then they made their own centimeter cubes out of plastic modeling clay, put them together, changed the shape of some of them, and wondered if the volume was the same or different.

Engage students in the focus question

Does changing the shape change the volume?

- The volume has to be the same because we haven't added any plastic modeling clay or taken any away.
- If we turned the plastic modeling clay back into centimeter cubes, there would be 8 of them so the volume hasn't changed.
- I made 4 of the cubes into a ball and my object looks bigger now so there is more volume.

Supporting questions

If you took the plastic modeling clay in your rabbit (new shape) and reshaped it back into cubes, what do you think you would find?

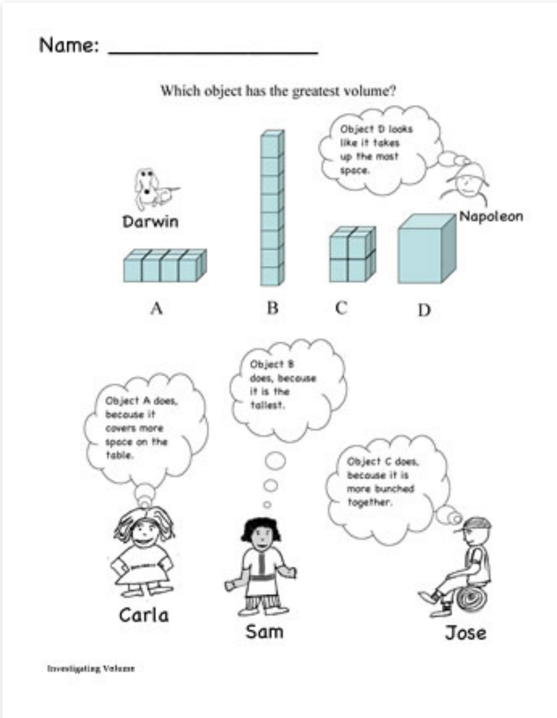
What was the volume of your original 8 plastic modeling clay centimeter cubes?

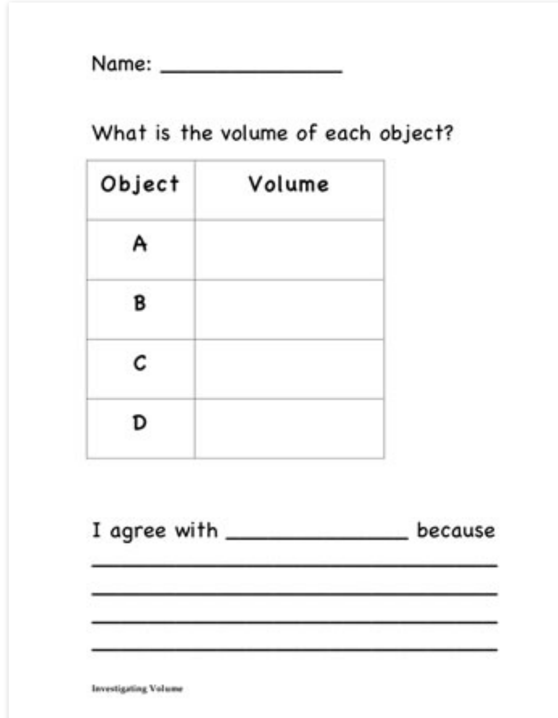
Did you add any plastic modeling clay to your original 8 cubic centimeters or take any away?

Recap the discussion

Summarize the idea that volume is the amount of space an object takes up. As long as we don't add any material or take any away, the volume will stay the same even if we change the shape of the object.

Volume Concept Cartoon





This cartoon was developed to probe students' understanding of volume as a 3-dimensional measure of the amount of space an object occupies. At issue is whether students differentiate volume from area or length, whether they see the small cubes as units of volume measure, and whether they realize measures require standard size units. It is typically used after Investigating Volume 3, *Does changing the shape of an object change its volume?*.

Things to look for in student responses

How do students use the information in the drawings to make inferences about the volume of the objects (in the data table)?

Some children may confuse volume with area, agree with Carla, and infer the volume of A is 8 squares, B is one square, and C is 4 squares.

Others may confuse volume with length, agree with Sam, and infer the volume of A is 4, B is 8, and C is 2.

Still others will "count the cubes" and conclude that A, B, and C have the same volume of 8 small cubes. (Of course, if these students only count "visible" cubes they may erroneously think C has only 6 or 7.) For the latter group of students (who attempt to "count the cubes") it is of great interest what they infer for D, whether they give only numeric values or units, and how they describe the units.

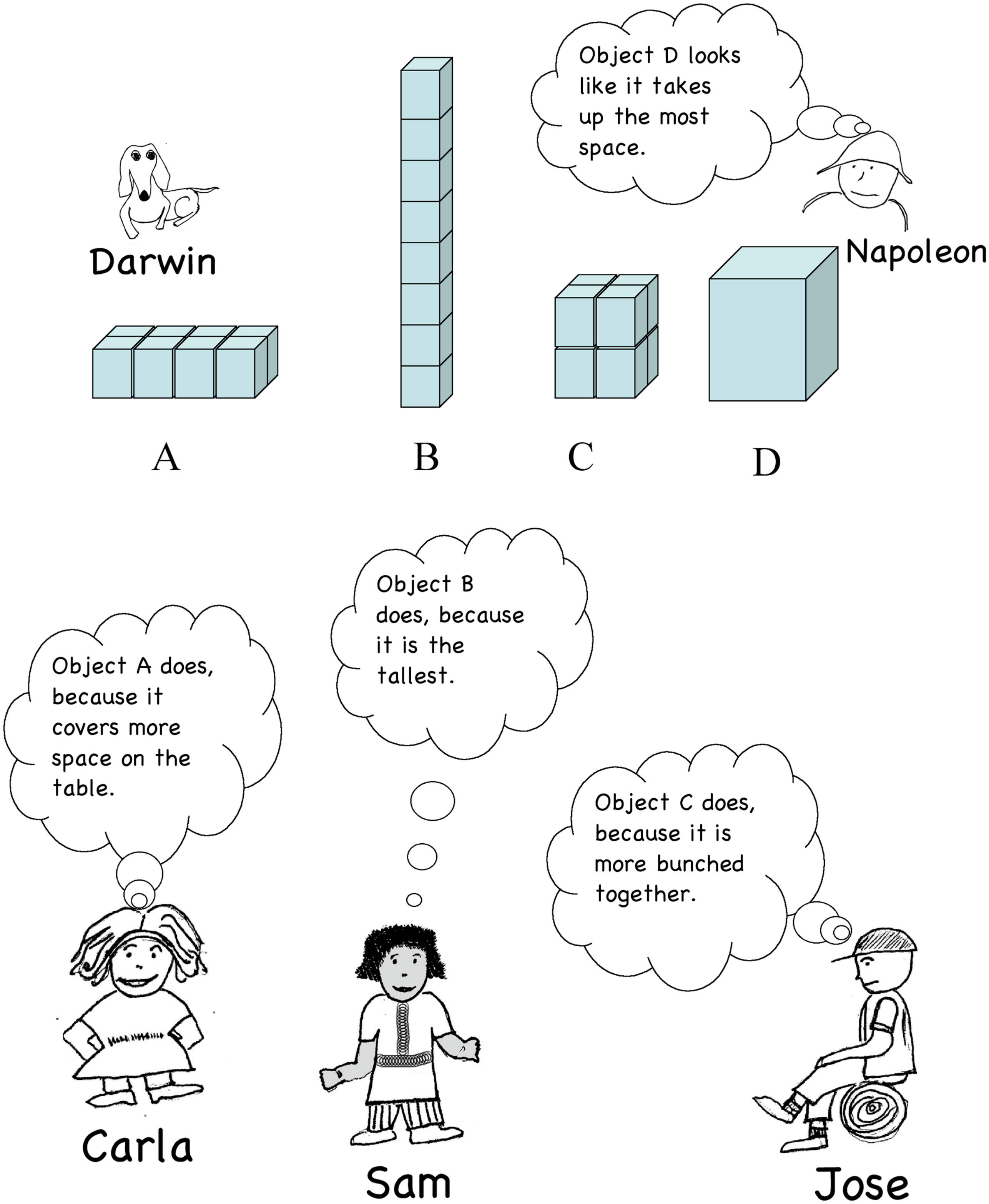
- Some students may mistakenly give D a value of 1 cube, showing when they count the cubes it does not matter what size they are.
- Others may simply say D has a volume greater than 8 cubes (noting the comparison with C and the fact that it is bigger in all dimensions) or give some wildly bigger number, such as 30.
- Still others may attempt to partition D into cubes and estimate its volume (estimating it has a volume of about 10-12 cubes). Some students may talk of the cubes as "cubic centimeters" while others simply refer to them as cubes.

Do students draw on the information in their data table in making arguments about which character they agree with?

Some students may view filling out the data table as an independent exercise. Others will make arguments that draw on the analysis provided, arguing that either A, B, C, or D has the greatest volume as noted above.

Name: ____________________

Which object has the greatest volume?



Name: _______________

What is the volume of each object?

Object	Volume
A	
B	
C	
D	

I agree with _______________ because

____

____

____

____

Investigating Volume 4:
How can we describe our personal objects?

Plan Investigating Volume 4

Materials … Weight … Standard Measures … Volume. The students have covered a lot of territory in their study of matter. In this capstone investigation, they apply their skills and understandings to a final task — fully describing the "personal objects" they brought to the first class.

Students first record some data about the materials, weight and volume of their personal objects. They then consider the entire collection of objects, graphing the range of data and placing all the objects on a weight line. This shift from describing a single object to describing a collection of objects is likely to be new for them. By the end of the investigation, they will be making some simple, general observations about the whole set of personal objects, describing common properties and using standard metric measures.

Learning Goals

- to use skills and concepts related to materials, weight, and volume
- to get more experience with data representations (graphs and the weight line)

Sequence of experiences		
1. Ask the question	All Class	10 Mins
2. Collect and record data about our objects	Small Groups	20 Mins
3. Make meaning	Discussion	15 Mins

** It is possible for this investigation to be performed within 45 minutes. However, it is recommended that Step 1 and Step 2 be completed within one session as collecting the data can often take longer than expected. Step 3 can be completed in a subsequent session along with any additional reflections you would like to complete this unit.*

Materials and Preparation

For the class:

- Post the investigation question in a place where all students can see it.
- Histogram 1: Number of Materials in Our Objects
- Histogram 2: Materials Our Objects are Made of
- Histogram 3: Estimated Volume of Our Objects
- The class weight line
- 3 volume reference blocks: 1, 10, 100 cubic centimeters (see the photo in Step 2).
    - 10 cubic centimeter reference is created by taping 10 centimeter cubes together
    - 100 cubic centimeter reference is created by taping 5 maple blocks labeled B (20 cubic centimeters) together

For each group:

- 1 gram weight set
- 2 pan balances

For each student:

- 1 personal or classroom object

1. Ask the question

All Class   10 Mins

Have the children retrieve their personal objects and hold them up for all to see.

What if you had to describe your object to someone far away who could not see it? How would you do it? How would a scientist do it?

Students may need help estimating volumes. You can create reference volumes from the centimeter cubes and maple blocks in your kit. The volumes created above are 1 cubic centimeter (1 cube), 10 cubic centimeters (10 cubes taped together), and 100 cubic centimeters (5 maple "B" blocks taped together).

As students share their ideas, recall some of the ways they have learned to describe objects in this unit, mentioning *materials*, *weight*, and *volume*.

Can you estimate how much your object weighs?

Can you estimate its volume?

What can you say about the materials?

Have students review the data-recording sheet. Let them know they will spend the whole class recording information about their objects and then considering how they are all alike and different. Point out the pan balances, the blocks you've set up to help them estimate volumes, the weight line where they will array their objects, and the histograms where they will enter their data.

Finally, share the investigation question with the students:

"How can we describe our personal objects?"

2. Collect and record data about our object

Small Groups   20 Mins   Notebook

Students weigh, measure, estimate volumes, and consider the materials that make up their objects. The data log in their science notebooks will guide them through the task of data collection.

You can help by:

- Watching for logjams at the pan balance and volume stations
- Helping students identify materials that are unfamiliar to them
- Reminding students how to use the gram weights if they are having trouble
- Helping estimate volumes, using the three volume blocks for reference (note that students are asked only for the range into which their object falls: less than 1cc, 1-10 cc, 10-100 cc, more than 100 cc)

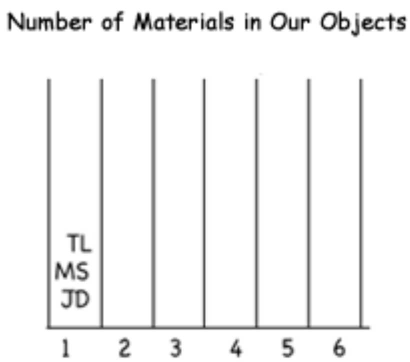
Crowd control: Having each person in a group start with a different measurement or observation will minimize the time students need to wait to use the pan balance or the volume blocks.

As students finish recording their data in their notebooks, ask them to share it with the class by

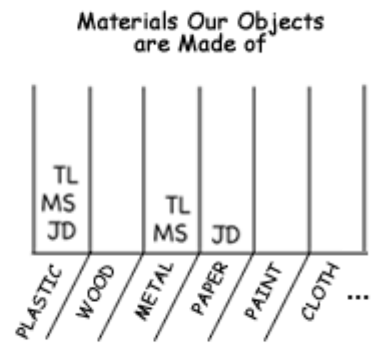
1. entering the materials data and volume data in the class histograms
2. putting their object in its proper place on the weight line.

You can help by demonstrating how to build the histograms, i.e., by entering students initials in the proper row or column, making sure the initials are written at about the same size, as shown in the examples.

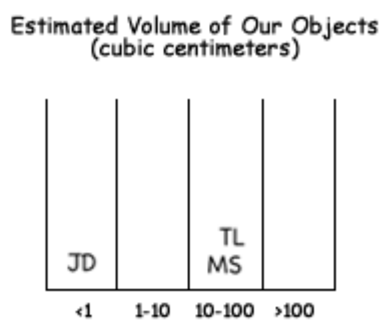
Note: By comparing the heights of the columns of initials in Histograms 1 and 2, students can quickly see how their objects make use of different materials.



Histogram 1: Number of Materials in our Objects



Histogram 2: Materials Our Objects are Made of

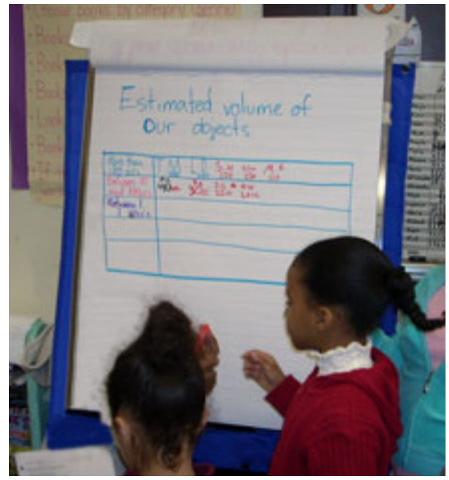


Histogram 3: Estimated Volume of Our Objects

Once all the volume data has been added, students can see where there are clusters of data and get a general picture of how the volumes of the personal objects are distributed across the four categories.

3. Make meaning

All Class 15 Mins



Purpose of the discussion

Students have collected a lot of data and the purpose of this discussion is have them help each other come up with statements (claims) about the whole collection of personal objects and point to the data that back up the claim (evidence). The discussion will help them use data to answer the investigation question, *How can we describe our personal objects?* Analyzing and interpreting data is an essential scientific practice.

Take 5 minutes for a few volunteers to share their descriptions of their own objects, using the data sheet in their notebooks. As they do, point to the representations of their individual data in the class histograms and the location of their object on the weight line.

Engage students in the focus question

Keeping attention on the histograms and weight line, recall the investigation question:

"How can we describe our personal objects?"

Look at all the data with the students.

How could we describe the whole collection of objects?

[Make Claims] The shift from describing a single object to describing a collection of objects is likely to be new for students, but as they study the data representations, they can be guided toward some simple, general observations about the entire data set.

What can we say about the number of materials our objects are made of?

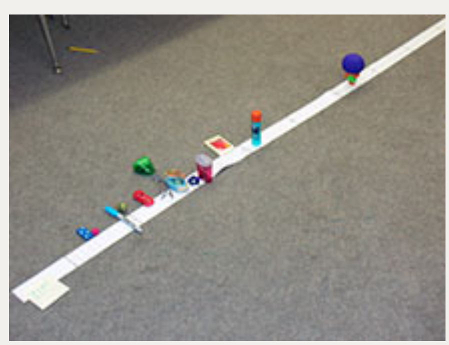
- They can figure out that each bar on the histogram is a different material so counting the bars tells you the number of materials.
  There are 14 different materials in our collection.
  Most of our objects are made of just two materials.

What can we say about the kind of materials our objects are made of?

- They can look at the height of the bar(s) to see which materials appear more frequently.
  The most common materials are plastic and wood. These materials don't break when you bring objects to school.

What can we say about the weight of the objects in our collection?

Like the histograms, this weight line is a *representation of data*. It shows not only the actual weights of the objects but also the relationships between the weights of different objects. For example, students can see the range between the lightest and heaviest objects and how the objects are distributed along that range. Are there clusters of objects? Where do they fall?



- They can discover the highest and lowest values in the weight data set, as well as the range of weights, as well as measures of central tendency.
  The heaviest object weighs _X_ grams.
  The lightest one weighs only _Y_ grams.
  The heaviest object is _Z_ grams heavier than the lightest one.
  Most objects are between _A_ and _B_ grams.

What can we say about the volume of the objects in our collection?

- They can discover clusters of weights, volumes, or materials.
  Most of our objects have a volume that is less than 100 cubic centimeters.

As you model generalizations, check that the students understand the relationship between the claim and the data (evidence).

> *Would you point to the place on the graph where you found this information?*

As students make claims, record the claim statements in a place where all can see the growing description of the set of personal objects. When the list is complete, ask students to suggest an explanation.

> *When we collected data on all our of our 26 objects, we see that plastic and wood are the materials used most often, their weights are between _X_ and _Y_, most have volumes between 10 and 100 cubic centimeters. Can you think of an explanation for why this would be true of our collections of objects?*
>
> *How did these graphs and the weight line help us describe our whole collection of objects?*

Congratulate students on their careful and thoughtful work as scientists!

Science Background

Throughout the grade 3 curriculum, students will work with a set of materials cubes. These are 8 cubes that are of equal shape and size, but made of different materials. By comparing these cubes to each other in a variety of ways, learners will discover that objects with equal volume may have very different weights, depending on the material they are made of. Each cube is approximately 1 inch or 2.5 cm on each side. The volume is 1 cubic inch or 15.6 cubic cm. If cubes are not marked, label each cube as shown below.

The Material Cubes

Pine (Pi):
The lightest cube is made of wood from a pine tree. The mass of this cube is approximately 7 gm. The mass may vary slightly. Pine is a soft wood that is used for furniture and timber. Pine is a low density wood, because it comes from fast growing trees.

Oak (Oa):
The second wooden cube is made from an oak tree. Oak is a much stronger and harder wood than pine. Oak has a greater density than the pine cube, so this cube is heavier. It's mass is approximately 13 gm. It is also typically darker in color than pine.

Nylon (Ny):
The nylon cube is white and plastic. Nylon is made from petroleum products. Nylon is often used to make fabric (an inexpensive alternative to silk), but can also be made into a hard plastic, as is this cube. The mass of the nylon cube is approximately 18 gm.

Acrylic (Ac):
The acrylic cube appears as a clear plastic. Because acrylic is clear, as well as stronger and less dense than glass, it is often used for outdoor windows and skylights. Acrylic is a term referring to man-made materials containing some form of acrylic acid. The mass of the acrylic cube is approximately 19 gm.

PVC (PV):
The PVC cube is grey and plastic. PVC stands for Polyvinyl Chloride which is an inexpensive and very durable material, often used in vinyl siding, magnetic stripe cards, and pipes for plumbing. Although the production of PVC is dangerous to health and the environment, it is one of the largest revenue generators of the chemical industry. The mass of the PVC cube is approximately 22 gm.

Aluminum (Al):
The aluminum cube is shiny and silver-colored. Its low density and strength makes it ideal for the construction of airplanes and other vehicles. Aluminum is the most abundant element in Earth's crust. The mass of the aluminum cube is approximately 44 gm.

Steel (St):
The steel cube is black and metal. Steel is an alloy of mostly iron and a bit of carbon. The symbol for iron in the periodic table is Fe, which is the stamp on the cube. The addition of carbon makes it stronger than Iron, but also more brittle. Steel is often used in the construction of buildings and vehicles. The mass of the steel cube is approximately 128 gm.

Copper (Co):
The copper cube is reddish-brown and metal. Copper is a natural element with the symbol Cu in the periodic table. Because of its high ability to conduct electricity, copper is often used for electrical wires and computer circuit boards. It is also used to make pennies, but since the rise in price of copper in the 1980's it is now only used as a coating over other metals. The mass of the copper cube is approximately 147 gm.

Curriculum Kit

How to Obtain a Kit

Information on how to obtain a materials kit is available on the Inquiry Project website (inquiryproject.terc.edu) in the Grade 3 Curriculum.

Curriculum Kit Materials

Materials are listed for a classoom of 24 students split into 6 groups of 4. Your classroom may require modifications of this list.

Sets in the Kit:

- 6 sets of 54 piece hexagram metric weights
- 6 sets of 4 blocks:
  - 2cm x 9cm x 1cm maple block (A)
  - 2cm x 2cm x 5cm maple block (B)
  - 3cm x 5cm x 1cm maple block (C)
  - 3cm x 3cm x 2cm maple block (D)
- 6 sets of 8 materials cubes (1" x 1" x 1")
  - oak
  - pine
  - acrylic
  - pvc
  - nylon
  - aluminum
  - copper
  - steel
- 6 sets of 15 items:
  - piece of cardboard, approx 2"x2"
  - plastic-covered copper wire,approx 6" long
  - bare copper wire; approx 6" long
  - piece cotton cloth fabric, approx 2"x2"
  - wooden spoon (ice cream type)
  - metal spoon
  - plastic spoon
  - metal key
  - steel bolt
  - 3-oz paper cup
  - rubber eraser
  - plastic counting bear
  - steel washer
  - wooden coffee stirrer
  - pencil

Other Materials:

- 1 aluminum cube, cut in half
- 1 pine cube, cut in half
- 1 classroom measure line
- 1 roll aluminum foil
- 1 pillar candle
- 1 tray balance
- 3 lbs plastic modeling clay
- 6 trays
- 12 pan balances
- 120 wooden coffee stirrers
- 180 plastic counting bears
- 250 metal washers
- 600 jumbo paper clips
- 500 cubes (1cmx1cmx1cm)
- 24 plastic knives
- 48 small paper plates
- 1 polystyrene foam rectangular prism (10cm x 10cm x 20cm)
- 6 polystyrene foam rectangular prisms (6"x12"x1")

Classroom Supplies:

- flip chart
- 24 pencils
- paper bag
- 3 boxes that appear identical but are filled with object that have clearly different weights (e.g. 3 crayon boxes — 1 filled with cotton balls, 1 filled with crayons, 1 filled with pennies)
- index cards
- 24 scissors
- variety of classroom items for weighing (e.g. stapler, ruler, board eraser)

Refill/Replacement Kit

- 6 polystyrene foam rectangular prisms (6"x12"x1")
- 120 wooden coffee stirrers
- 3 lbs plastic modeling clay