What Is Scientific Measurement?

Inquiry Focus

Measure—making measurements using non-standard and standard units to understand the advantages of a standard measurement system

Group Size Groups

Class Time 15 minutes

Advance Preparation

You may wish to provide a variety of small objects that students can use for units. Whenever possible, include different sizes of a given type of object (such as erasers or pencils).

Procedure Tips

Encourage students to be creative when thinking of their unit of measurement, especially items that could vary in size from one sample to another.

Expected Outcome: The measurements using nonstandard units will not be as accurate or precise as those made with metric units.

Answers

1. Sample answer: The measurement using metric units was closer to our original measurement. The object that the other group used was not the same size as ours, so its measurement was different.

2. Scientists use a standard system so that other scientists can understand their data and compare their own results to it.
Measuring With SI
Unlocking the Key Concept
This activity will help students practice making measurements using the SI unit for measuring length and then making conversions for length.

Inquiry Focus
Measure—measuring various items in the classroom in the SI unit for length

Group Size Pairs
Class Time 15 minutes
Advance Preparation (10 minutes)
Make and record various measurements before class to know generally what to expect from students’ measurements.

Procedure Tips
1. If necessary, review how to use a meter stick.
2. Make sure partners take turns making the measurements.
3. Emphasize that students should measure as accurately and precisely as possible. If necessary, review the difference between these two terms.

Answers
1. Sample answer: I think our measurements were accurate, because the measurements we made were the same or very close to others’ measurements of the same objects.

Sample data table

<table>
<thead>
<tr>
<th>Object</th>
<th>Length</th>
<th>Length in mm</th>
<th>Object</th>
<th>Length</th>
<th>Length in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of classroom</td>
<td>9.5 m</td>
<td>9000.5 mm</td>
<td>Height of table</td>
<td>70 cm</td>
<td>700 mm</td>
</tr>
<tr>
<td>Length of pencil</td>
<td>16 cm</td>
<td>160 mm</td>
<td>Width of printer</td>
<td>35 cm</td>
<td>350 mm</td>
</tr>
<tr>
<td>Width of book</td>
<td>32 cm</td>
<td>320 mm</td>
<td>Length of paper</td>
<td>28 cm</td>
<td>280 mm</td>
</tr>
<tr>
<td>Length of scissors</td>
<td>20 cm</td>
<td>200 mm</td>
<td>Width of window</td>
<td>1.2 m</td>
<td>1200 mm</td>
</tr>
<tr>
<td>Height of door</td>
<td>2 m</td>
<td>2000 mm</td>
<td>Height of locker</td>
<td>1.5 m</td>
<td>1500 mm</td>
</tr>
</tbody>
</table>
2. Sample answer: The team’s measurements were precise, because the measurement was the exactly the same each time. I don’t know whether their measurements were accurate. To know that I would need to know the actual length of the classroom.

### A Unit of SI

**Unlocking the Key Concept**

This activity will help students understand density, including how to measure an irregular solid and calculate its density.

**Inquiry Focus**

- **Measure**—collecting quantitative data about an object’s mass and volume
- **Calculate**—subtracting one measurement of volume from another and then dividing the mass of an object by its volume to find its density

**Group Size** Pairs

**Class Time** 15 minutes

**Safety**

Tell students they should gently slip the rock into the graduated cylinder to avoid spills and breakage.

**Advance Preparation** (10 minutes)

**Sample data table**

<table>
<thead>
<tr>
<th>Step</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of object (g)</td>
<td>13.4 g</td>
<td>13.4 g</td>
</tr>
<tr>
<td>Volume of water (mL)</td>
<td>50 mL</td>
<td>50 mL</td>
</tr>
<tr>
<td>Volume of water plus rock (mL)</td>
<td>55 mL</td>
<td>55 mL</td>
</tr>
<tr>
<td>Volume of rock (cm³)</td>
<td>5 cm³</td>
<td>5 cm³</td>
</tr>
<tr>
<td>Density of rock (g/cm³)</td>
<td>2.68 g/cm³</td>
<td>2.68 g/cm³</td>
</tr>
</tbody>
</table>

### Inquiry Warm-Up

#### How Do Math and Science Work Together?

Collect small rocks that easily fit into a graduated cylinder. Set up a laboratory balance at one or more stations.

**Alternate Materials**

Any small, irregularly shaped object can be used instead of a small rock, as long as the object is completely immersed when put into the water. Examples include a marble, nut, or bolt.

**Procedure Tips**

1. If students measure volume first, remind them to completely dry the rock before they measure its mass.
2. If necessary, review how to use the laboratory balance.
3. Remind students that one cubic centimeter equals one milliliter.
4. To determine density, students should divide the mass in grams by the volume in milliliters to get a result in grams per milliliter (g/mL).

**Answers**

1. Sample answer: Yes, the change in volume would be different for different objects, because the change in volume is directly related to the volume of the object put into the water.
2. To make sure the data were reliable
Class Time 15 minutes

Advance Preparation (5 minutes)

Provide one box of crayons for each team. You can use any size box of crayons; for students who are less comfortable with calculations, you may wish to use 8-crayon boxes, while more proficient students can use larger boxes. Make sure that some of the crayons have been used so that the crayons are different sizes.

Procedure Tips

After students have performed the activity and answered the questions, lead a class discussion of estimation and calculation in other scientific scenarios.

Expected Outcome: A single crayon will have a mass of about 4.5 grams. The total mass will vary depending on the sizes of the crayons.

Answers

1. Sample answer: I multiplied the mass of one crayon by the number of crayons in the box to make an estimate. I used the skills of calculating and estimating.

2. Sample answer: Some crayons may be larger or smaller than others. I could improve my prediction by finding the mass of several crayons of different sizes and finding the average, and then using that value to calculate the total mass.

Sample data table

<table>
<thead>
<tr>
<th>Trial</th>
<th>Mass</th>
<th>Trial</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>136.3 g</td>
<td>4</td>
<td>136.3 g</td>
</tr>
<tr>
<td>2</td>
<td>136.4 g</td>
<td>5</td>
<td>136.3 g</td>
</tr>
<tr>
<td>3</td>
<td>136.3 g</td>
<td>6</td>
<td>136.3 g</td>
</tr>
</tbody>
</table>

Answers

1. We used four significant figures. The balance measures to the nearest decigram.

2. Sample answer: Our measurements were both precise and accurate. Our six measurements never differed by more than 2 dg. Two of our measurements were exactly the same as the mass measured by the teacher.

3. Sample answer: We would check to see if the balance we used was in good working order. We would also make sure we were using the balance correctly each time we measured the mass of the flask. If necessary, we could use a different balance.
**Quick Lab**

**Math Tools in Science**

*Unlocking the Key Concept*

This activity will help students practice calculating the percent error of experimental measurements.

**Inquiry Focus**

*Measure*—measuring the mass and volume of an irregular solid in metric units

*Calculate*—subtracting and dividing measurements to calculate volume, density, and percent error

**Group Size** Pairs

**Class Time** 20 minutes

**Advance Preparation** (15 minutes)

Make sure the copper pieces are pure copper and not an alloy, or the known density will be incorrect. Record the mass and volume of each piece so you can identify errors in students’ measurements if their percent errors are high.

**Procedure Tips**

1. Review with students, if necessary, how to use a balance and graduated cylinder.
2. Caution students to avoid splashing water out of the graduated cylinder in Step 3, because doing so would affect the accuracy of their measurement.
3. Explain why simply finding the difference between experimental and true values is less meaningful than dividing this difference by the true value. For example, a difference of 1 g/mL is more significant if the true value is 10 g/mL than if it is 100 g/mL.

**Answers**

1. Answers will depend on the magnitude of students’ errors.
2. Sample answer: I think my measurement is accurate because the percent error is low.

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**Recognizing Trends**

*Unlocking the Key Concept*

This activity will help students practice making and interpreting graphs based on data in a table.

**Inquiry Focus**

*Graph*—making a line graph from data in a table to identify a trend in the data

*Predict*—using the graph to predict a value outside the range of values in the table
**Group Size** Pairs

**Class Time** 20 minutes

**Safety**

Caution students to wipe up any spilled water immediately. Tell students to handle the thermometers with care; use only non-mercury thermometers. Remind students not to eat the sugar cubes.

**Advance Preparation** (10 minutes)

Purchase enough sugar cubes so that each pair of students has three cubes. Make sure you select small sugar cubes so they will dissolve quickly. Prepare cold, lukewarm, and hot water for each team. Do not heat the water so much that it would cause burns.

**Procedure Tips**

Store the thermometers in a container of room temperature water so that students start with thermometers at the same temperature.

**Sample Data Table**

<table>
<thead>
<tr>
<th>Temperature (° C)</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18° C</td>
<td>134 sec</td>
</tr>
<tr>
<td>42° C</td>
<td>80 sec</td>
</tr>
<tr>
<td>55° C</td>
<td>43 sec</td>
</tr>
</tbody>
</table>

**Answers**

1. Sample answer: As water temperature increases, the time it takes the sugar to dissolve decreases.

2. Students should predict that sugar will dissolve faster in 80° C water than in the warmest water they tested, because the trend in their graphs showed that the time it takes sugar to dissolve decreases as water temperature increases.

**Quick Lab**

**Working With Models**

**Unlocking the Key Concept**

This activity will reinforce students’ understanding of how scientists use models in scientific investigations.

**Inquiry Focus**

*Make Models*—making representations of atoms involved in three chemical reactions

**Group Size** Pairs

**Class Time** 15 minutes

**Advance Preparation** (5 minutes)

Make the three models yourself in advance to anticipate how students might use the materials in this activity.

**Procedure Tips**

1. Introduce the concept of a chemical reaction by explaining that atoms can combine to produce new substances.

2. After students have completed their models, encourage them to walk around and view the other models. Then, lead a class discussion on which models were easiest to understand.

**Answers**

1. Sample answer: Carbon monoxide was easiest to model because it only used two atoms. Calcium carbonate was hardest to model because it had many atoms and we weren’t sure which atoms went together.
2. Sample answer: An advantage is that chemical reactions are too small to see easily, so models can help in understanding what occurs in a reaction. A disadvantage is that a model isn’t exactly the same as the actual thing, so it may be misleading about what really occurs.
**Direct Inquiry** Collect the appropriate number of strong bar magnets, plastic straws, metric rulers, rolls of masking tape, and paper clips. Test your bar magnets in advance to make sure they are strong enough for the procedure.

**Open Inquiry** In addition to the materials collected for the Directed Inquiry, collect the appropriate number of various sized steel balls (ball bearings).

**Alternative Materials**

**Both Versions** Any small metal objects, such as small washers, could be used instead of paper clips, as long as the objects are attracted to the magnet.

**Safety**

**Both Versions** Remind students to wear safety goggles.

**Procedure Tips**

**Both Versions**

1. To introduce students to this activity, begin by leading a discussion about the gravitational force between Earth and the moon. Ask: *Is there evidence that there is gravitational force between Earth and the moon?* (Students might mention that the moon stays in orbit around Earth or that the gravitational attraction between Earth and the moon causes tides on Earth.) Point out that gravity is a force that attracts all bodies to each other. Earth’s gravity is strong enough to hold the moon in orbit around Earth.
   
   Ask: *Why is Earth’s gravitational force greater than the moon’s?* (because Earth has much greater mass than the moon) Discuss what students know about the relationship between distance and the strength of gravitational force. Ask: *How could you test a hypothesis about distance and gravity?* (Students might suggest trying to measure the gravitational force between two objects at one distance and then at another.) Point out that such an experiment would be difficult to perform in a laboratory. Ask: *Is there another common force you know of that acts over a distance between objects?* (magnetism) Ask: *How could investigating magnetism tell us something about gravity?* (We could carry out an experiment to test a hypothesis about magnetism as a model for gravity.) Make sure students understand that magnetism will be used in their investigations only as a way to model gravity and that the two forces are not the same. For instance, all objects with mass exert a force of gravity, while magnetism is a force that is only associated with certain types of objects.

**Directed Inquiry**

1. Tell students they will use a model to investigate a question about gravity. As a model for the force of gravity, they will test a hypothesis about magnetic force.

**Open Inquiry**

1. Sample hypothesis for Procedure Step 1: As the distance between a magnet and paper clips increases, magnetic force decreases.

2. Sample hypothesis for Step 2: As the distance between a magnet and iron objects increases, magnetic force decreases.

3. Students should make a data table to record their observations as they vary the distance between the magnet and the test objects.

**Sample Data Table**

**Directed Inquiry**

<table>
<thead>
<tr>
<th>Length of Straw</th>
<th>Number of Paper Clips</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mm</td>
<td>31</td>
</tr>
<tr>
<td>1 cm</td>
<td>25</td>
</tr>
<tr>
<td>1.5 cm</td>
<td>18</td>
</tr>
<tr>
<td>2 cm</td>
<td>15</td>
</tr>
<tr>
<td>2.5 cm</td>
<td>10</td>
</tr>
<tr>
<td>3 cm</td>
<td>6</td>
</tr>
</tbody>
</table>

**Answers—Analyze and Conclude**
Direct Inquiry

1. The independent variable was the distance between the magnet and the paper clips; the dependent variable was the number of paper clips picked up.

2. Students’ line graphs should show a descending line from left to right. Sample answer: The graph reveals that as distance increased, the bar magnet picked up fewer paper clips.

3. Sample answer: Yes, it provided the data I needed to show that magnetic force decreased as the distance between the magnet and the paper clips increased.

4. Sample answer: As distance increases, magnetic force decreases.

Open Inquiry

1. Sample answer: The independent variable was the distance between a bar magnet and the test object. The dependent variable was whether the bar magnet attracted the test objects.

2. Sample answer: We used the metric ruler to mark different distances on the plastic straw and then attached the straw to the magnet with the straw extending from the magnet at the marked lengths. These lengths of straw made sure the distances from the magnet to the paper clips varied the way we wanted.

3. Students’ line graphs should show a descending line from left to right. Sample answer: The graph reveals that as distance increased, the bar magnet attracted fewer of the test objects.

4. Sample answer: As distance increases, magnetic force decreases.

Answers—Post Lab

Directed Inquiry

1. Sample answer: Because both magnetic force and the force of gravity are similar in some ways, I can infer that as distance increases, the force of gravity decreases.

2. Sample answer: Using magnetism as a model for gravity in an investigation is good because they both are attractive forces. But using magnetism as a model may be misleading because the two forces are not the same.

3. Sample answer: I learned that using a model for a natural process can provide some understanding for the natural process. After performing this experiment, I want to know whether the results of using this model would actually be valid for gravity.

Communicate—Students’ blog entries should explain how magnetism can be used in the lab as a model for the force of gravity. The entry should also include a description of the experiment as well as its results and conclusion. Finally, the blog entry should tie the conclusion drawn from the experiment to an explanation of gravitational force in relation to distance.

Open Inquiry

1. Sample answer: Using magnetic force as a model for the force of gravity, I can infer that as distance increases, the force of gravity decreases.

2. Sample answer: Studying the force of gravity in the laboratory would be difficult to do. Using magnetic force as a model makes a lab investigation more practical. A drawback is that magnetic force and the force of gravity may be similar in some ways, but they are different forces.

3. Sample answer: I learned that using a model can provide some understanding for a natural process. I still want to know what changes scientists might make to this experiment so that it would better represent the inputs and outputs of gravity.

Communicate—Whichever medium students choose to use, they should design a presentation that clearly explains the details and results of their magnetism experiment. The presentation should also include a clear explanation about how magnetism can be used as a model to investigate a question about the force of gravity.

Can You Name the Safety Equipment?

Inquiry Focus

Infer—using prior knowledge and common sense to identify safety equipment based on a description of how it is used
Prepared to Be Safe in the Field

Unlocking the Key Concept
This activity will help students practice preparing for field investigations in order to keep themselves and other living things safe.

Inquiry Focus
Design Experiments—learning about preparations for potential safety concerns when conducting field investigations

Group Size Pairs
Class Time 15 minutes

Materials
The terrarium should include soil, plants, invertebrates such as insects, and a small vertebrate such as a frog, salamander, lizard, or snake. Safety equipment should include anything that might be needed in a field investigation, such as nitrile gloves, safety goggles, boots, sunscreen, hat, sunglasses, insect repellent, first aid kit, and compass. Plastic gloves will tear too easily in the field, nitrile or heavy plastic garden type gloves are preferred.

Advance Preparation (20 minutes)
Create a classroom terrarium, if you do not already have one. Place the terrarium and safety equipment in a central location in the classroom for students to examine.

Procedure Tips
1. Remind students not to touch or use any safety equipment unless instructed to by a teacher.
2. Sample answer for Step 2: fire; fire extinguisher, glass breakage; first aid kit, chemical splashes; safety goggles

Answers
1. Sample answer: I would wear plastic gloves, handle the animal gently, return it to its natural environment right away, and wash my hands after handling it.
2. Sample answer: You should always work with a partner so if you are injured, your partner can tell an adult. You should always work with an adult for help in case of emergencies.
Quick Lab

How Would You Respond to These Emergencies?

Unlocking the Key Concept

This activity will help make students aware of what to do if a lab emergency occurs.

Inquiry Focus

*Design Experiments*—identifying appropriate safety equipment for use in different lab emergencies

**Group Size** Pairs

**Class Time** 10 minutes

**Advance Preparation** (15 minutes)

1. Use sticky notes to number all the safety equipment in the lab that would be needed for the listed emergencies. Leave the equipment in its usual place. All of the equipment must be visible to students.

2. All the emergencies listed could potentially happen, and would likely involve calling 911 for assistance. Make yourself familiar with the protocol for students to notify the instructor or to make the 911 call. Your school should have a set of protocols for the staff to follow for emergencies. If not, talk to your supervisor to see if guidelines could be established.

**Procedure Tips**

1. Sample answer for Step 1: You should immediately tell a teacher or other adult and follow their instructions exactly.

2. Students may not immediately understand how some equipment, such as an eye wash station, works. Demonstrate how the equipment is used. You may also wish to prepare descriptions of the equipment for students to refer to.

<table>
<thead>
<tr>
<th>Emergency</th>
<th>Equipment Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>An electrical fire occurs.</td>
<td>[Class C or ABC fire extinguisher]</td>
</tr>
<tr>
<td>Someone gets cut on a piece of broken glass.</td>
<td>[First-aid kit]</td>
</tr>
<tr>
<td>A chemical is splashed in someone’s eyes.</td>
<td>[Eyewash station]</td>
</tr>
<tr>
<td>Someone’s clothes catch on fire.</td>
<td>[Fire blanket]</td>
</tr>
</tbody>
</table>

**Answers**

1. Sample answer: So you can quickly find the equipment in case of an emergency

2. Sample answer: Follow directions carefully, listen to the teacher, wear protective equipment