Sugar Crystal Challenge

Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on surface area and how the shape of sugar crystals may differ as they are grown from sugars of different grades of coarseness. Students explore surface area, nanostructures, and work in teams and participate in hands-on activities.

Lesson Synopsis

The "Sugar Crystal Challenge" explores how nanostructures can influence surface area, and how the sugar can be modified to different levels of coarseness without impacting molecular structure. Students work in teams and explore different states of sugar as it relates to surface area and molecular structure.

Age Levels

8-14.

Objectives

- Learn about nanostructures.
- Learn about crystals.
- Learn about surface area.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- nanostructures
- surface area
- problem solving
- teamwork

Lesson Activities

Students learn about how surface area can change at the nanoscale. Students work in teams to explore different forms of sugar at different levels of coarseness. They then predict how sugar crystals grown from different sugar solutions might be different at the molecular level depending upon the coarseness of the original sugar. Student make predictions, conduct research, and present their proposal to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- TryNano (www.trynano.org)
- National Nanotechnology Initiative (www.nano.gov)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- NSTA National Science Education Standards (www.nsta.org/publications/nses.aspx)
- NCTM Principles and Standards for School Mathematics (http://standards.nctm.org)

Recommended Reading

- The Science of Sugar Confectionery (ISBN: 0854045937)
- Understanding Nanotechnology (ISBN: 0446679569)

Optional Writing Activity

- Write an essay or a paragraph about how the surface area of different grades of sugar might be important to a baker who wanted to coat doughnuts with sugar. Would they need more granulated sugar than powdered sugar? Why, or why not?

Sugar Crystal Challenge

For Teachers:
Teacher Resource

◆ **Lesson Goal**

Lesson focuses on surface area and how the shape of sugar crystals may differ as they are grown from sugars of different coarseness. Students explore concepts of surface area and nanostructures, and work in teams and participate in hands-on activities including growing sugar crystals from different sugar samples.

◆ **Lesson Objectives**

Learn about nanostructures.

- Learn about crystals.
- Learn about surface area.
- Learn about teamwork and working in groups.

◆ **Materials**

Student Resource Sheet

- Student Worksheets
- Microscope or camera scope for classroom use
- Dissolving Challenge: One set of materials for each team:
  - Two clean thermal glass cups or measuring cups of at least 4 cup capacity (can be used in crystal challenge too), access to warm water, 1 teaspoon granulated sugar, 1 teaspoon powdered sugar
- Crystal Challenge: One set of materials for each team:
  - Two clean thermal glass cups or measuring cups of at least 4 cup capacity, 2 lengths of thin cotton string that is 1.5 times as long as the cup is tall, 2 Pencils or sticks, weight to hang on string (washer, screw), 3 cups of granulated sugar, 3 cups of powdered or confectioners' sugar, 2 cups very hot water (poured by adult)

◆ **Procedure**

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.

2. Dissolving Challenge:
   a. Students pour one cup of warm water into each of two glass cups
   b. Students add a teaspoon of powdered or confectioners' sugar in one cup and a teaspoon of granulated sugar in the other.
   c. They observe which dissolves faster and answer questions regarding how surface area impacted the results

◆ **Procedure (continued)**

3. Crystal Challenge:
   a. Teacher/adult first pours one cup of very hot water in to each of the two cups.
   b. Students add 3 cups of each type of sugar into individual cups and stir to dissolve -- the water will appear perfectly clear when the sugar is dissolved. Note - alternate approach is to boil the water to dissolve the sugar -- if this approach is taken, an adult should prepare boiled sugar solutions.
   c. Soak the string into the sugar water and tie one end to the pencil so that the other end hangs vertically in the sugar solution. A weight (washer, screw) can be added to ensure the string stays straight. You may also prepare the strings ahead of time, soaking them in the sugar solutions and letting them dry. With this method, there will be starter crystals on the string before being placed in the sugar solutions which can speed up the crystal process as the starter crystals provide a place for new crystals to form.
   d. Observe the cups each day for four - seven days
   e. Record observations during growth
   f. Examine each of the resulting crystals under a microscope and record observations in table provided.

4. Evaluation - Students complete evaluation/reflection sheets

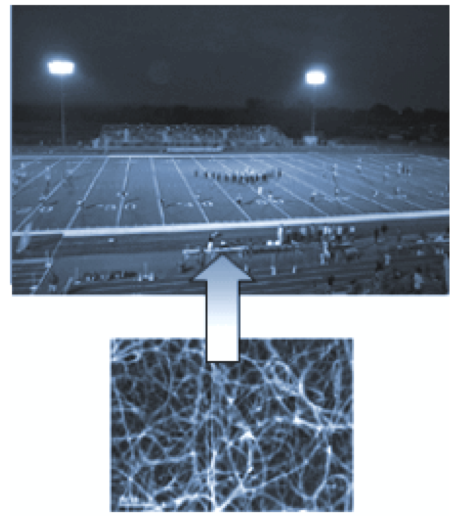
◆ **Time Needed**

Two to three 45 minute sessions over the course of 7 days.

◆ **Tips**

- Boiled water is preferable to "hot" water, so is recommended if your facility can safely use boiled water under adult supervision.
- If a microscope is not available, any of the new video scopes can also be used and attached to a monitor or computer screen for viewing. Examples are "Eye Clops" ($25-$45) or the Carson zPix Digital Microscope ($79).

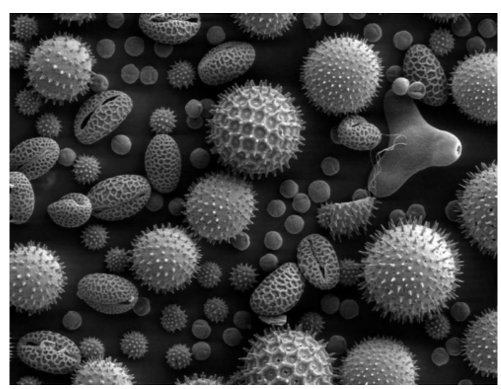
For Students:
What is Nanotechnology?



Four grams of carbon nanotubes has the same surface area of a football field.

Imagine being able to observe the motion of a red blood cell as it moves through your vein. What would it be like to observe the sodium and chlorine atoms as they get close enough to actually transfer electrons and form a salt crystal or observe the vibration of molecules as the temperature rises in a pan of water? Because of tools or 'scopes' that have been developed and improved over the last few decades we can observe situations like many of the examples at the start of this paragraph. This ability to observe, measure and even manipulate materials at the molecular or atomic scale is called nanotechnology or nanoscience. If we have a nano "something" we have one billionth of that something. Scientists and engineers apply the nano prefix to many "somethings" including meters (length), seconds (time), liters (volume) and grams (mass) to represent what is understandably a very small quantity. Most often nano is applied to the length scale and we measure and talk about nanometers (nm). Individual atoms are smaller than 1 nm in diameter, with it taking about 10 hydrogen atoms in a row to create a line 1 nm in length. Other atoms are larger than hydrogen but still have diameters less than a nanometer. A typical virus is about 100 nm in diameter and a bacterium is about 1000 nm head to tail. The tools or new "scopes" that have allowed us to observe the previously invisible world of the nanoscale are the Atomic Force Microscope and the Scanning Electron Microscope.

◆ **Scanning Electron Microscope**



The scanning electron microscope is a special type of electron microscope that creates images of a sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. In a raster scan, an image is cut up into a sequence of (usually horizontal) strips known as "scan lines." The electrons interact with the atoms that make up the sample and produce signals that provide data about the surface's shape, composition, and even whether it can conduct electricity. The image to the right is Pollen from a variety of common plants, magnified about 500 times. It was taken with a scanning electron microscope at the Dartmouth Electron Microscope vwww.dartmouth.edu/~emlab/gallery.

For Students: Nanotechnology Applications

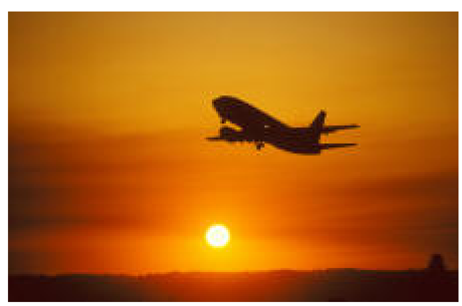
Materials that exhibit different physical properties resulting from changes at the nanoscale have already opened the door to many new applications. Many of these applications are still in various stages of research, but some are already available commercially.

For example, clothing material has been integrated with nanoparticles to create stain resistant cloth. Auto manufacturers enhanced bumpers with nanocrystals, making them stronger. Color filters and colored lamps have been created by altering the optical properties of a suspension (through varying of the size and shape of the colloidal particles in the solution). Carbon nanotubes have been designed for products such as bike frames and tennis rackets to enhance strength and reduce weight.

◆ **Biomedical Applications**

Nanotechnology is expected to have a significant impact on improving the quality of health care through early and reliable diagnostics of diseases, better drugs, targeted drug delivery, improved implants, and other applications. Biosensors - using a combination of nanomaterials, novel device fabrication techniques and advances in signal processing - are being developed for early detection of several life threatening illnesses. These sensors use carbon nanotubes or silicon nanowires which can host the probe molecule that seeks to identify the signature of a particular condition or illness. Nanobiosensors using this approach are expected to be mass-produced using techniques developed by the computer chip industry. Nanotechnology will also play an important role in therapeutics. Two areas where nanotechnology is expected to make an impact are synthesis of improved drugs using principles of nanotechnology, and targeted drug delivery. Specifically, a certain family of molecules known as dendrimers (these are repeatedly branched molecules) are considered as candidates for effective delivery of drugs. These large polymers have a pouch-like configuration at their centers which can be used to host drugs inside the molecules that carry them to their destination.

◆ **Transportation Applications**



One of the major contributions that nanotechnology can make in the transportation sector is lighter weight and high strength composite materials ("composites") for the construction of airplanes and automobiles. Composites are created from two or more materials with significantly different physical or chemical properties. These properties remain distinct within the finished structure. The promise of nanocomposites is that they will be lighter and stronger than other kinds of widely used composites.

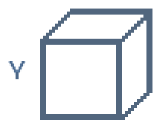
Student Resource:
What is Surface Area?

Surface area is the measure of how much exposed area an object has. It is expressed in square units. If an object has flat faces, its surface area can be calculated by adding together the areas of its faces. Even objects with smooth surfaces, such as spheres, have surface area.

◆ Square Surface Area Formulas

The surface area of a cube may be expressed by the formula:

x = 6Y2 (or 6 times Y times 2)

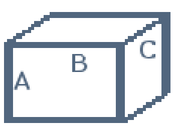


The drawing to the left shows a cube, where Y equals the length of each side. Because it is a square, all sides are equal in length. To determine the surface area of the cube, you first have to find out the area of one side. The area of one side is Y x Y or Y^2. To find the surface are of the cube, you need to multiply the area of one side by 6. If, for example, the length of Y equalled 10 mm, then the area of one side would be 100 square mm and the area of the cube would be 600 square mm.

◆ Rectangular Surface Area Formulas

The surface area of a rectangle may be expressed by the formula:

x = 4AB + 2AC



With a rectangle, all the sides are not equal...but there are three different lengths to be measured. If the drawing above, these are represented by A, B, and C. To determine the are of the front of the rectangle, we'll need to multiply A x B. Since there are four surfaces on the rectangle that are equal in size, we need 4 x A x B as one part of our formula to determine the surface are of the dimensional rectangle. We'll also need to determine the area of the two smaller surfaces. In this case, we'll need to multiply A x C. And, because there are two of these "faces" to the rectangle, we need 2 X A X C for the full surface area formula. If, for example, the length of A equalled 10mm, and B equalled 30mm and C equalled 15mm then:

A times B = 300mm, so 4AB= 1200 square mm

A time C = 150mm, so 2AC= 300 square mm

So the surface area of the dimensional rectangle is 1500 square mm

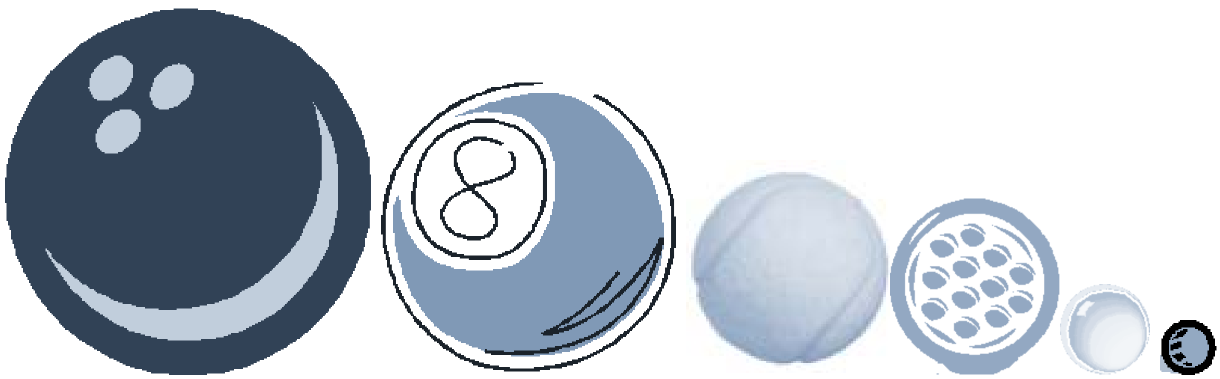
◆ Why Surface Area Matters

At the nanoscale basic properties of particles may vary significantly from larger particles. This might include mechanical properties, whether the particle conducts electricity, how it reacts to temperature changes, and even how chemical reactions occur. Surface area is one of the factors that changes as particles are smaller. Because chemical reactions usually take place on the surface of a particle, if there is an increased surface area available for reactions, the reaction can be very different.

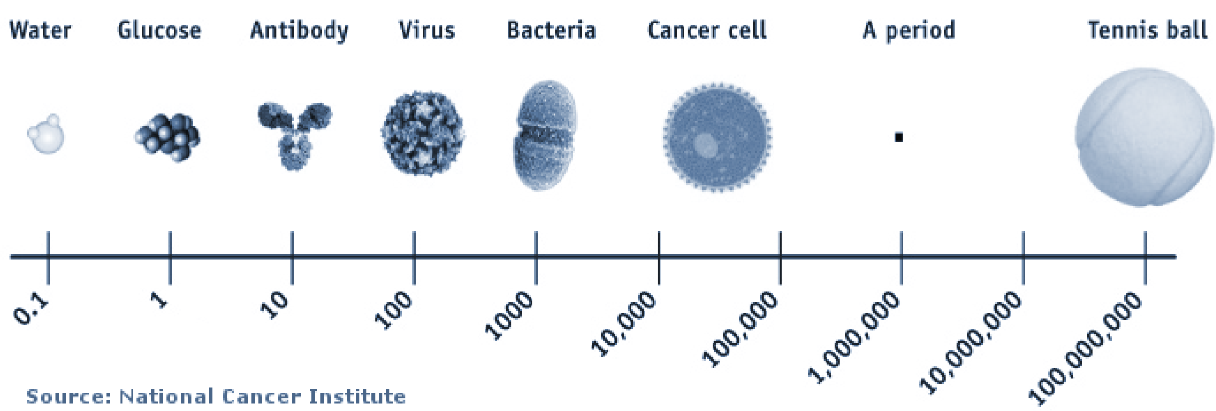
Student Resource: How Big is Small?

It can be hard to visualize how small things are at the nanoscale. The following exercise can help you visualize how big small can be!

The following are drawings of items you may recognize…. a bowling ball, a billiard ball, a tennis ball, a golf ball, a marble, and a pea. Think about the relative size of these items.



Now take a look at the chart below that was developed by the National Cancer Institute (U.S.) and think about how much smaller the various items are…moving down from the familiar tennis ball. The "." on this page is 1,000,000 microns -- quite gigantic compared to a virus or a single molecule of water (H_20).



Sugar Crystal Challenge

Student Activity: Dissolving Challenge

You are part of a team of engineers who has been given the challenge of exploring how the surface area of sugar changes depending upon what state it is in. Sugar is available in various crystal sizes which impacts their use or application.

◆Types of Sugar

Sanding Sugar: Coarse-grained sugars, such as sanding sugar are often used to add sparkles when decorating baked goods such as cookies and candies. The "sparkle" results from light reflecting off the large sugar crystals.

Granulated Sugar: Normal granulated sugars have a grain size about 0.5 mm across and are most commonly used as table sugar for use in coffee or tea.

Caster Sugar: Caster Sugar is a finer grades result from selectively sieving granulated sugar until it is about 0.35 mm. It is commonly used in baking.

Powdered Sugar: Powdered sugar is also known as confectioner's sugar or icing sugar and is a very finely ground form of sugar. A grain of confectioner's sugar is about 0.060 mm, while a grain of icing sugar is about 0.024 mm. These are used a great deal in cooking, where a sugar that dissolves quickly into a fluid is preferred. It is used in making icings or frostings and other cake decorations.

Regardless of the coarseness of sugar, the base sugar molecules remain the same.

◆ Impact on Surface Area:

The difference in surface area in a gram of sugar is much greater in a gram of powdered sugar than in a gram of caster sugar. And the surface area of a gram of caster sugar is greater than the surface area of a gram of granulated sugar.

◆ Dissolving Challenge:

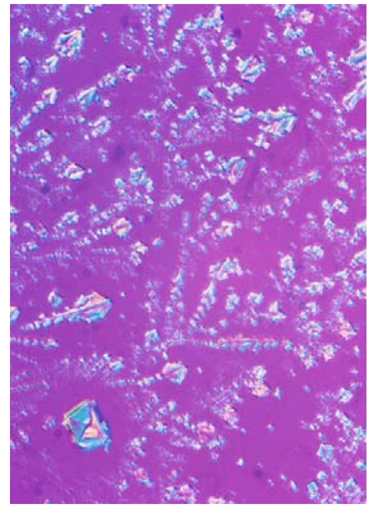
Fill two clear glasses with one cup of warm water. At the same time, put a teaspoon of powdered or confectioners' sugar in one cup and a teaspoon of granulated sugar in the other. Answer the following questions:

Which sugar dissolved faster?

Why do you think this was true? How did surface area impact which dissolved first?

Student Activity: Crystal Challenge

◆ What is a Crystal?



A crystal is a solid substance in which atoms, molecules, or ions are arranged in an orderly repeating pattern extending in three spatial dimensions. The process of forming a crystalline structure from a fluid or from materials dissolved in a fluid is called crystallization. The crystal structure formed from a fluid depends on the chemistry of the fluid and the physical conditions in the surrounding area, such as what the air pressure is. Snowflakes, diamonds, and table salt are examples of crystals. Crystallography is the scientific study of crystals and crystal formation.

◆ What is Saturation?

Substances such as sugar can only dissolve up to a certain point in water -- then if you add more sugar it will remain in its solid form -- this point is called saturation. In this lesson, we'll dissolve two different types of sugar into hot water. Then, as the water evaporates over time, the solution will become saturated so the sugar will attach to the string and form solid molecules of sugar that will stick to the string. These molecules will attract more and more sugar molecules until crystals form. Over time, more water will naturally evaporate and the sugar water solution will become even more saturated so the thickness of the sugar crystals on the string will grow. Your finished string of sugar crystals will be comprised of roughly a quadrillion (1,000,000,000,000,000) molecules.

◆ The Challenge

As a team discuss and come to a hypothesis about the following question: If you dissolve sugars of different coarseness (granulated, powdered, cubes) in water and then grow sugar crystals, will the resulting crystals appear the same under a microscope, or will there still be a difference in appearance based on the initial coarseness of the sugar? Answer the questions in the box below:

Describe your answer and include at least two supporting arguments for your hypothesis.   Why? 1. 2.

Student Activity: Crystal Challenge (continued)

◆ **Testing Stage**

You have received a set of materials from your teacher, including:

- Two clean thermal glass cups or measuring cups of at least 4 cup capacity
- 2 lengths of thin cotton string that is 1.5 times as long as the cup is tall
- 2 Pencils or sticks
- Weight to hang on the string (washer, bolt)
- 3 cups of granulated sugar
- 3 cups of powdered, or confectioners' sugar
- 2 cups very hot water (should be poured by teacher)

◆ **Observation**

As a team you'll be attempting to grow sugar crystals from two different sugars - granulated and confectioner's. Remember that granulated sugars have a grain size about 0.5 mm across while a grain of confectioner's sugar is about 0.060 mm. Observe the granulated and confectioner's sugar under a microscope or using a digital TV or monitor scope. Record your observations in the chart below, which you'll complete after growing crystals.

	Granulated Sugar	Confectioner's Sugar	Crystal Grown from Granulated Sugar Solution	Crystal Grown from Confectioner's Sugar Solution
Describe what you see in words				
Sketch what you see				

Student Activity:
Crystal Challenge (continued)

◆ Investigation / Research

1. Mark one glass cup "granulated" and the other "confectioner's" to distinguish them during the investigation.

2. Add 3 cups of the appropriate sugar into the marked cup.

3. Ask an adult to pour one cup of hot water into each of the two cups.

4. Stir the sugar into the water until it appears perfectly clear -- this means the sugar is dissolved. Note - an alternate approach is to heat the water to a boiling point to dissolve the sugar -- if this approach is taken, the teacher should prepare all boiled liquid sugar solutions for students.

5. Soak a piece of cotton string into each of the sugar solutions and place it on a plate to dry for at least ten minutes. The longer it dries, the better. With this method, there will be starter crystals on the string before being placed in the sugar solution -- this can speed up the crystal process as the starter crystals provide a place for new crystals to form.

6. For each cup, tie the appropriate string onto the end of a pencil so that the other end of the string hangs vertically in the sugar solution. You may wish to tie a screw or bolt to the bottom of the string to make it hang straight in the sugar solution.

7. Check the growth over time and make note of your observations.

8. Examine a sample of the crystals that grew from granulated sugar and from confectioner's sugar under a microscope as you did with the original sample sugars. Record observations in table provided on the previous page.

Student Activity: Crystal Challenge (continued)

◆ **Evaluation Phase**

Complete the following questions as a group:

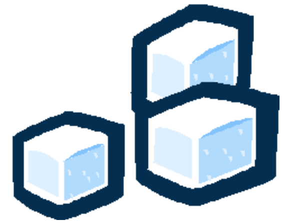
1. Compare the crystals that grew from the granulated sugar and those that grew from the confectioner's sugar? Be sure to be specific and include illustrations if that helps you.

2. How did your hypothesis about the crystals compare to the actual results? Were you surprised by what you found?

3. List two uses of sugar where the sugar with the greater surface area that would have been a better choice than a courser sugar. Why do you think this is true?

4. Suggest another use for the principle of nanotechnology. For example, engineers are testing the use of nanostructures to increase the surface area of solar panels to make them more efficient because there is greater opportunity for the sun to reach a surface. Can you think of a similar idea?

5. What is the most interesting aspect of nanotechnology or nanostructures you learned during this lesson?



For Teachers:
Alignment to Curriculum Frameworks

Note: All lesson plans in this series are aligned to the National Science Education Standards which were produced by the National Research Council and endorsed by the National Science Teachers Association, and if applicable, also to the International Technology Education Association's Standards for Technological Literacy or the National Council of Teachers of Mathematics' Principles and Standards for School Mathematics.

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of the activities, all students should develop an understanding of
- Properties of objects and materials

CONTENT STANDARD E: Science and Technology
As a result of activities, all students should develop
- Abilities of technological design

CONTENT STANDARD G: History and Nature of Science
As a result of activities, all students should develop understanding of
- Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry
As a result of activities, all students should develop
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science
As a result of their activities, all students should develop an understanding of
- Properties and changes of properties in matter

CONTENT STANDARD E: Science and Technology
As a result of activities in grades 5-8, all students should develop
- Abilities of technological design
- Understandings about science and technology

◆Principles and Standards for School Mathematics (ages 6 - 18)

Measurement

- understand measurable attributes of objects and the units, systems, and processes of measurement.
- apply appropriate techniques, tools, and formulas to determine measurements.

Connections

- recognize and apply mathematics in contexts outside of mathematics.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.

Technology and Society

- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.