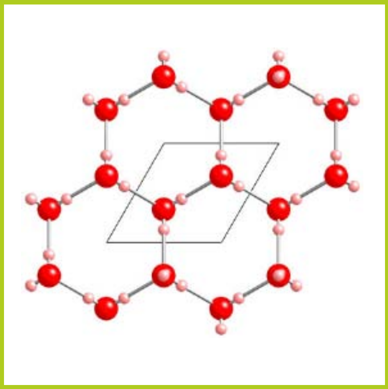
LESSON 1 ICE IS A MINERAL

DIRECTORY

PHOTO GALLERY



This activity develops pre-cursor understanding about the characteristics of ice as a mineral, compared to other minerals, particularly in terms of hardness.

SCIENCE & LITERATURE

"Those instruments which the Mineralogist takes to his assistance in the examination of the hardness are—the knife in half-hard and soft fossils, the steel in hard, and the file in perfectly hard fossils…HARD is a fossil that cannot be scraped with a knife, but rather gives fire with steel…VERY HARD, on which the file makes a weak impression…and EXTREMELY HARD, on which the file makes no impression, but rather receives an impression from the fossil…HALF-HARD is a solid fossil which does not strike fire with steel, but may in some measure be scraped with a knife…Those solid fossils are SOFT which may be easily scraped with a knife, but suffer no impression from the nail…VERY SOFT are all solid fossils which may not only be easily scraped with a knife, but also receive an impression from the nail."

—Abraham Gottlob Werner (1805). Excerpt from an original imprint of the English translation *Treatise on the External Characters of Fossils*

We often think of scientific data as *quantitative*, that is, precisely expressed through the use of mathematics. Yet precision can also be attained through the use of language to describe qualities of phenomena, producing *qualitative* data. The leading geologist of his times, Werner used straightforward descriptive words to propose a relative hardness scale. Through his carefully defined meanings, he was able to present a whole system of how to identify and classify "fossils," in those days referring to rocks, minerals, and ores (rocks that contain metals).

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CONCEPT OVERVIEW

This activity develops precursor understanding about the characteristics of ice as a mineral, compared to other minerals, particularly in terms of hardness.

Concepts:

- Solids
- Crystal
- Minerals
- Hardness
- Scales

This activity provides a concrete experience of:

- Evidence of ice as a mineral
- Comparing the relative hardness of ice to other objects
- Creating a relative hardness scale

PRE K–GRADE 2 CONCEPTS

- A mineral is a special kind of solid with a crystalline structure.
- A crystalline structure is a regular shape formed by the arrangement of the building blocks (atoms and molecules) of the mineral.
- Ice is a solid with a crystalline structure.
- Ice is a mineral.
- Ice is harder than some things and softer than others.
- A scale of measurement is used to compare properties of phenomena.

GRADE 3–5 CONCEPTS

- Geologists define a mineral as a naturally occurring solid with a crystalline structure.
- "Crystalline structure" is a regular geometric arrangement of atoms and molecules that compose the mineral.
- A rock is a mixture of different minerals
- Water ice is a naturally occurring solid with a crystalline structure.
- Ice is a mineral.
- The hardness of ice can be measured by comparing it with other objects (a relative hardness scale) or by comparing it to a set of criteria (an absolute hardness scale).
- Different scales of measurement are used to compare different properties of phenomena.

LESSON SUMMARY & OBJECTIVES

Geologists teach that a mineral is a naturally occurring solid with a crystalline structure. This activity explores how ice compares to other minerals, and how thinking about ice as a mineral may help us as we explore for the presence of ice in the Solar System. Specifically, this activity looks at the property of *hardness*, an object's resistance to scratching, which depends on the molecular bonds. We can quantify our understanding of hardness by making a relative hardness scale.

Objective 1: Notice that ice forms as crystals

Although the individual molecules are too small for us to see, we can view crystal matrices of ice and we can understand that when ice freezes, its forms a crystalline structure.

Objective 2: Notice that ice fits the definition of a mineral

Geologists define a mineral as a naturally occurring solid with a crystalline structure. Ice fits this definition and can be compared with other minerals.

Objective 3: Notice that ice is harder than some things and softer than others

Geologists categorize minerals according to their physical characteristics. Hardness is one characteristic that students can experience directly.

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STANDARDS

PROJECT 2061 BENCHMARKS

4D—The Physical Setting Structure of Matter

GRADES K–2, PAGE 76

Objects can be described in terms of the material they are made of (clay, cloth, paper, etc.) and their physical properties (color, size, shape, weight, texture, flexibility, etc.).

1C The Nature of Science: The Scientific Enterprise

GRADES K–2, PAGE 15

In doing science, it is often helpful to work with a team to share findings with others. All team members should reach their own individual conclusions, however, about what the findings mean.

NSES

Content Standard B Physical Science: Properties of objects and materials

GRADES K–4, PAGE 127

Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with the other substances. These properties can be measured using tools such as rulers, balances, and thermometers.

Content Standard A Science as Inquiry: Abilities necessary to do scientific inquiry

GRADES K–4, PAGE 122

Communicate investigations and explanations. Students should begin developing the abilities to communicate, critique, and analyze their work and the work of other students. The communication might be spoken or drawn as well as written.

Content Standard E Science and Technology: Understanding about science and technology

GRADES K–4, PAGE 138

Scientists and engineers work in teams with different individuals doing different things that contribute to the results. This understanding focuses primarily on teams working together, and secondarily, on the combination of scientist and engineer teams.

ESSENTIAL QUESTION

How can we understand ice as a mineral?
How is ice considered a mineral? What features does ice share with other minerals? What is a crystalline structure?

ACTIVITY QUESTION

How hard is hard?
What observations can we make about the hardness of ice as one of the qualities that define it as a mineral? What can we say, draw, write about the hardness of ice that we look at, touch, and examine in class?

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BACKGROUND

What is Hardness?

Hardness is a property of a mineral that depends on the strength of its molecular bonds. Hardness is one measure of the strength of the structure of the mineral relative to the strength of its chemical bonds. The hardness of a mineral is often measured by what it takes to make a scratch mark on it. Minerals with small atoms, packed tightly together with strong covalent bonds throughout tend to be the hardest minerals. The softest minerals have metallic bonds or even weaker van der Waals bonds as important components of their structure. Hardness is not the same as brittleness, which is a measure of how easily something breaks and is related to the crystalline structure of the mineral.

How is ice a mineral?

Geologists view ice, especially large-scale glacial ice, as a mineral. Ice shares many features with other minerals, but it is also different in some important ways. Most solids are denser than their own liquid form. Water is very different. Its solid form (ice) is less dense than its liquid form (water), and therefore ice floats in water. This characteristic keeps bodies of water, ponds, lakes, rivers, and oceans, dynamic. Our planet's ability to support life is partly a result of the amazing properties of ice.

Ice meets the criteria of the definition for a mineral:

- Solid (for ice: below 0° Celsius, 32° Fahrenheit)
- Homogenous (all parts of it are the same)
- Naturally occurring, (on Earth where it is below freezing)
- Has a crystalline structure
- Has a definite chemical composition (H_2O)
- Formed by inorganic processes

(Hurlburt, C. and Klein, C., Manual of Mineralogy. NY: John Wiley and Sons, Inc.)

Ice is a mineral with the chemical formula H_2O. However, it must be in a frozen state to qualify as a mineral. The solid phase of water normally occurs at or below 32 °F, 0 °C, or 273 °K. Ice belongs to the hexagonal crystal system. Ice has a Mohs hardness of 1.5.

Whose idea is it, anyway?

In the history of science, we learn that scientific ideas are credited to individuals who first publicize their insights within the science community. Often, many people are working on the same ideas and it is difficult to tell whose idea a discovery really is. For example, there is a controversy regarding Werner and Mohs about the origin of the relative hardness scale:

In 1774, when he was 24, Abraham Gottlob Werner published his *Treatise on the External Characters of Fossils*, in which he presents a whole system of how to identify and classify rocks, minerals, and ores (rocks that contain metals) and proposes a relative hardness scale. "Werner became one of the most famous "geologists" of the period, and was extremely influential in educating many of the "early" developers of modern geological theory" (Stumfall. 2003).

His treatise was translated into English in 1805, in elegant, straightforward prose. Some of the language is archaic, especially the use of the word fossil. In those days, the word "fossil" referred to the whole range of rocks, minerals, and ores. Today's meaning for fossil includes petrified evidence of life. In Werner's time, such specimens were called "petrifactions." Another phrase that might strike us as quaint is "give fire with steel," that is, make a spark by striking the rock with steel.

In Summary:

Degree of Hardness	German	Description
EXTREMELY HARD	Äusserst Hart	FILE makes *no impression*
VERY HARD	Sehr Hart	FILE makes *a weak impression*
HARD	Hart	FILE makes *a considerable impression* STEEL *gives fire (makes sparks)*
HALF-HARD	Halb-Hart	KNIFE scrapes STEEL *gives no fire (makes no sparks)*
SOFT	Weich	KNIFE *scrapes easily* NAIL *makes no impression*
VERY SOFT	Sehr Weich	KNIFE *scrapes easily* NAIL makes *impression*

Source: Werner, Abraham Gottlob (1749–1817). A treatise on the external characters of fossils. Translated from the German of Abraham Gottlob Werner by Thomas Weaver. Imprint Dublin, M.N. Mahon, 1805.

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Mohs' Or Werner's Hardness Scale: Who Should Get The Credit?

Comparison of the original writings of Abraham Gottlob Werner and Carl Friedrich Christian Mohs reveals many similarities in the relative hardness scale of minerals developed by each. Many of Werner's students were publishing materials from his lectures without permission, which angered him even into his later years because his former students were "robbing his authorship". Friedrich Mohs was one of Werner's pupils.

After Werner died in 1817, Mohs was asked to fill Werner's position as professor at the *Bergakademie* in Freiberg. Mohs (1824) elaborates his hardness scale in *The Treatise on Mineralogy, or the Natural History of the Mineral Kingdom* for which Mohs is given credit for inventing the hardness scale. Both the methodologies for determining hardness as well as the scale itself as elaborated by Mohs are eerily similar to Werner's methodologies and scale.

Werner's hardness scale has a greater number of minerals than Mohs and is divided into seven major categories. Mohs' scale uses most of the same minerals that Werner used in his. One of the major differences between the two is that Mohs' scale is exactly inverted, moving from soft to hard instead of hard to soft. Mohs also simply divided a couple of Werner's categories.

Apparently, Mohs was not a newcomer to using the work of others for his own benefit and had a history of publishing new similar systems that others had developed, which included public accusations of plagiarism in reference to another mineralogy book that Mohs authored.

Source: Stumfall, Marilynn Y., Dept. of Geological Sciences, California State University, San Bernardino, and Leatham, W. Britt, Department of Geological Sciences, California State University, San Bernardino.

Reading the Mohs Relative Hardness Scale

For over 150 years, field geologists have used the Mohs Hardness Scale, named for Friedrich Mohs. Some say Mohs failed to credit Werner properly for his ideas (see Background for more discussion). Mohs added a new twist: he selected a set of ten commonly recognized minerals and assigned each of them a number from 1 to 10, arranged from softer to harder.

Geologists use the Mohs scale as a way to estimate the hardness of rocks, minerals, and metals when they are in the field. Hardness is related to the strength of the chemical bonds holding the molecules together. Hardness can be measured by scraping one specimen against another. A harder specimen will scratch the surface of a softer specimen. An arrangement from softer to harder on an ordinal scale from one to ten gives a relative value.

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Today, hardness is also measured for industrial and scientific purposes by instruments designed to exert precise pressures on a given specimen. Measured in this way, shown on the table below, you can see that while Gypsum has a hardness of 2, it does not mean that it is twice as hard as 1 on Mohs Relative Hardness scale; it is actually 3 times as hard as talc.

Mohs Scale of Hardness	Actual Relative Hardness	Mineral	Associations and Uses
1	1	Talc	Soapstone, Talcum powder. Magnesium silicate.
2	3	Gypsum	Alabaster, Plaster of Paris. Gypsum is formed when seawater evaporates from the Earth's surface. Calcium sulfate.
3	9	Calcite	Limestone and most shells, contain calcite. Calcium carbonate.
4	21	Fluorite	Used in the making of enamels. Calcium fluoride.
5	48	Apatite	A component of tooth enamel and bones. Three variations.
6	72	Orthoclase	Feldspars, a group of rock-forming minerals that form over half the Earth's crust.
7	100	Quartz	Most common mineral on Earth.
8	200	Topaz	Hardest silicate along with beryl. Emerald and aquamarine are varieties of beryl with a hardness of 8.
9	400	Corundum	Sapphire and ruby are varieties of corundum. Twice as hard as topaz.
10	1600	Diamond	Four times as hard as corundum.

Other examples:

2.5	Fingernail
2.5–3	Gold, Silver
3	Copper penny
4–4.5	Platinum
4–5	Iron
5.5	Knife blade
6–7	Glass
6.5	Iron pyrite
7+	Hardened steel file

Typically, in the field, a scientist would take a few items of known hardness, ready to do scratch tests.

For example, if you had a copper penny with you and you found a soft rock, you might want to know how relatively soft it is. If the penny left a scratch mark, then you would know that the rock's hardness is less than 3. Then you might use your fingernail—and if didn't leave a scratch mark, you would know that the rock was between 2.5 and 3. Back in the laboratory, you might conduct different tests to learn more.

ACT OUT THE SCIENCE

Whole Group Mime Activity: *Movement Integration Mediating Experience*
Activate students' prior knowledge about bonds.

Before the science story, remind students about or actually play the game, *Red Rover, Red Rover*, in which two teams face each other held together by strong "bonds," hand to hand, calling out to send a runner to try to break through the "bonds." Connect the idea of the breaking apart of the hands as the runner races through with breaking the molecular bonds in a scratch test for hardness.

Ice Rocks: The Story of The Hardness of Ice
In which students form into a geometric matrix, modeling the crystalline structure of ice, and show how scratching the ice breaks the bonds.

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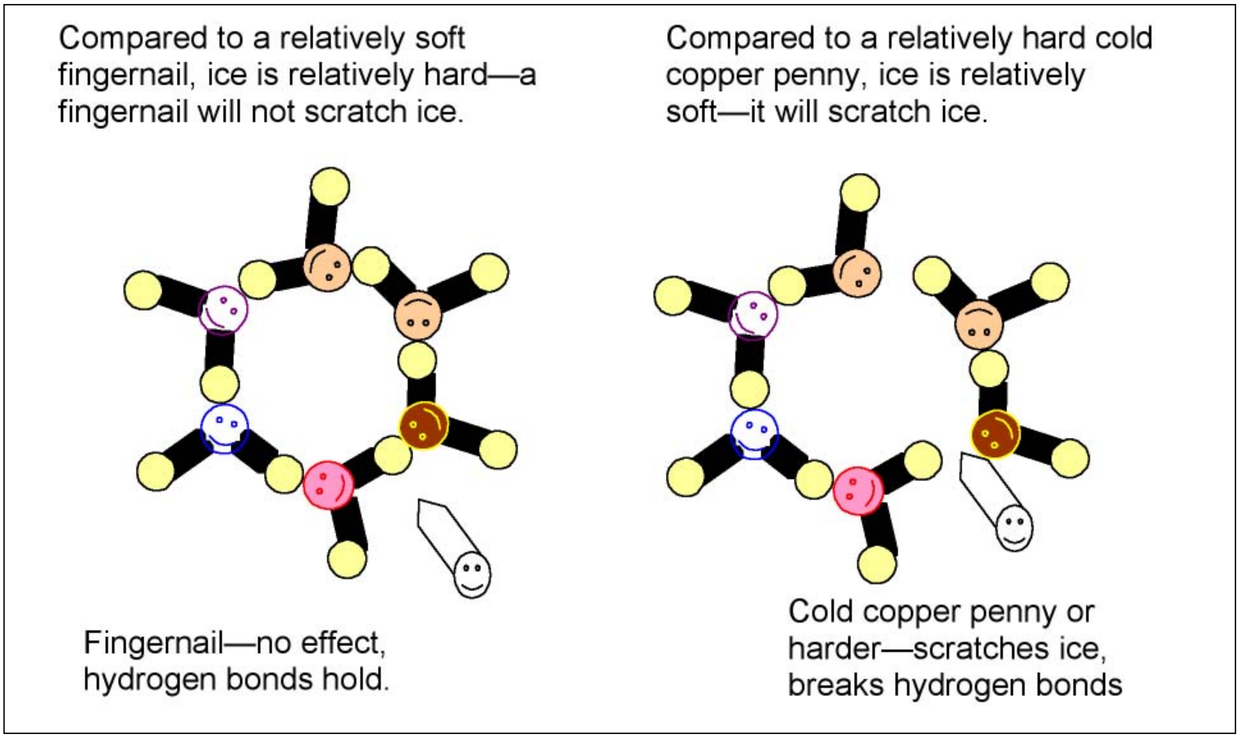

Narrative	Movement	Concept
Hardness is measured by scratching. Come to think of it, itching is measured by scratching, too. (scratch, scratch, scratch all over) Oh, that feels so much better! Say, do you like hard rock? Well, here's the hard rock question: what gets scratched when we scratch a rock, when we scratch a rock with a hard rock? What? That's right! What gets scratched when we scratch a rock to test if it's a hard rock? To test for hardness? Let's explore this *mimediately*. Everyone stand up. Let's see if we can figure this out together.	Have everyone stand up in an open area. Make sure everyone has plenty of room to move without bumping into anyone or anything.	We are going to use the whole body to create an experiential model of ice.

Narrative	Movement	Concept
Let's imagine that your arms are different kinds of bonds—molecular bonds—the different ways atoms use to bind to each to form molecules. These bonds have different strengths that hold a mineral's molecules together in their crystalline structure. Strong as these bonds are, they move just a bit all the time: they stretch out and in, they can bend this way and that way, they can stretch AND bend, and they can twist. They can Do the Twist! Okay, now we are going to make models of ice—out of ourselves! H_2O forms two kinds of bonds, *covalent* and *hydrogen*.	Move the arms distinctively with each mention of a type of bond. Move the arms with each mention of the way bonds move.	Molecules are connected by different kinds of bonds. Oxygen and Hydrogen form *covalent bonds*—Oxygen's outer energy orbital is completed by 2 Hydrogen's sharing their electrons. They happen to bind geometrically forming an angle of ~104° as liquid water, stretching to ~109° as frozen ice.
Imagine now, that your head is an atom of oxygen, O, and each of your hands, a hydrogen atom, H. So we have H_2O. Let your arms represent the *covalent bonds* that bind each hydrogen atom to the oxygen atom, by sharing electrons. Stretch out your arms as if you were about to give a bear hug. This is the same kind of very strong bond that holds carbon atoms together in diamonds, the hardest mineral we know of.	The head is the O atom; the two fists are the two H atoms. The arms represent the covalent bond that holds the H close to the O.	This illustrates the parameters of molecular force fields in a dynamic, kinesthetic way, comparable to a graphic illustration. This sequence builds a precursor understanding of atoms and molecules.

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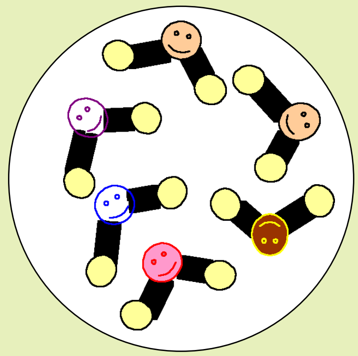
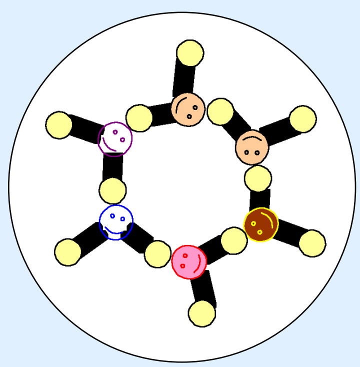
Narrative	Movement	Concept
In water, the Oxygen side of the molecule tends to attract the electrons and tends to have a slightly negative charge, while the Hydrogen side of the molecule tends to be more powerfully proton positive. When water is liquid, *hydrogen bonds* form briefly as the molecules slosh around—the proton positive H (the hands), binding for picoseconds to the electron-rich O (the back of the shoulders)—almost like a game of tag.	See illustration for guidance in helping students transform themselves from liquid water into the shape of an ice crystal. 	The emphasis here is on the difference in binding strength between the covalent bonds that connect H_2O through sharing of electrons (very strong bonds) and the hydrogen bonds that connect the relatively positive H protons to the electron-rich Oxygen lobes.
But as water starts to freeze, things slow down. As the outstretched arms bind to the back of the shoulders at the angle of a bear hug, they stretch and freeze (into angles of about 109°). We'll model this by making orderly hexagons out of ourselves.		The objective is to provide students with a precursor understanding of the notion of chemical bonds and the geometric structure of minerals—with ice as the focus.
Let's rewind into circles in close. As you do so, turn to your right and connect your left hand to the back of the next person's shoulder area to form a hydrogen bond that holds (or turn to your left and connect your right hand to the back of the next person's shoulder). These connections are the *hydrogen bonds*. You'll notice that we just fit six of us to form a ring—and we are now frozen ice crystals!		

Narrative	Movement	Concept
Now, let's invite a couple of people to scratch the ice with a fingernail. Look, no effect. The fingernail is not able to break the hydrogen bonds. The hydrogen bonds of ice are harder than a finger-nail. But what if we use a cold copper penny? Aha! The *hydrogen bonds* break loose, the penny scratches the ice, and so will anything harder than ice!	Invite a student to enact the scratching, first with to show that the "fingernail" (or alternative object) is softer than ice and does not scratch—the hydrogen bonds hold. Then invite the student to enact how a cold copper penny is harder than ice and scratches the surface, breaking the hydrogen bonds.	The scratch test enacted. Notice that it is the *hydrogen bonds* that break apart by scratching. The *covalent bonds* are much too strong (see Faraday's electrolysis experiment).

Small Group Mime Activity: *Movement Integration Mediating Experience*
Invite students to form small groups (about four to seven students), to create their own mime and narrated story about hardness or any property of ice as a mineral.

MATERIALS

The activity enables students to experience the hardness of ice. The activity works best when the ice can be kept at temperatures below freezing until just before observation. Ice that has been melting for a while may have qualities perceived by students as "soft."

For All Lessons, to Record Reflections, Observations, Calculations, etc.

- Science Notebooks: writing and drawing utensils.

Demonstration

Samples of objects for comparison of hardness (e.g. cold candy bar and room temperature candy bar; chalk and rock)

Main Activity

- Several 10, 20 or 25-pound blocks of ice (kept cold until just before observation)
- Plastic trays large enough to display ice and hold meltwater
- Work gloves (to handle the ice safely)

PRE K–2

- A variety of familiar objects to group into relative hardness and softness order (toys, plush animals, kitchen utensils, arts and crafts items, candies)

3–5

- A wide variety of found objects for hardness comparison (minerals, rocks, metals, game pieces, toys, candies and other objects)

Science Instruments

- Mohs Hardness Scale scratch test minerals and/or a hardness scale tool set composed of commonly available materials for scratch testing or
- Create your own collection of items appropriate for young students that might be used for scratch testing

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DEMONSTRATION

Purposes:

- To demonstrate the idea of a hardness scale;
- To demonstrate how a scientist thinks about hardness.

The Scratch Test

Hardness is a quality defined by the chemical bonds of a substance. How hard are the bonds holding on to one another? We can find out by trying to scratch a specimen. If the scratching implement is harder, it will leave a mark—the trail of broken chemical bonds. In the field, a geologist often carries a set of sample rocks, mineral, and metals to use as scratching implements, to test for hardness.

Demonstrate hardness of a few sample materials, by scratching the two objects together:

Examples:

Same object at different temperatures: A frozen chocolate bar (harder) SCRATCHES a chocolate bar at room temperature (softer).

Two different objects at the same temperature: Chalk (softer) LEAVES A STREAK on a blackboard made of slate (harder). Graphite in a pencil (softer) LEAVES A STREAK on paper (harder). In fact, the number of a pencil is an indicator of its hardness.

MAIN ACTIVITY

PREPARATION

Collect a sufficient number and variety of objects for students to interact with to observe and arrange with respect to perceived hardness and softness.

Objects may include toys, plush animals, household objects, rocks, minerals, candies, or any other handy objects around the classroom. These may be distributed in different stations around the room, so that students can work in small groups, or in a central area for working as a whole group.

Also, arrange an area with a selection of tools or objects with which to conduct a scratch test on a block of ice.

TEACHING TIPS

Explore

Scientific description requires precise use of words used as terminology. In everyday conversation, we assume that we understand what someone means by hard or soft—but there are times when need more information. How hard? How soft? Relative to what? Creating scales of measurement that can be agreed upon by a community of scientists is an important achievement. Imprecise as it is by today's technological standards, the Mohs Scale has been of practical use by field geologists for over 150 years. By giving young students a chance to devise their own relative hardness scales based on objects familiar to them, we can guide them toward precursor understandings about how scientists use relative scales.

Diagnose

Listen to student ideas about hardness. How do we compare objects? What criteria do we use to measure hardness? How do we test whether our scale is useful? This is also an opportunity to listen to students' ideas about other properties of rocks and minerals and may indicate other instructional strategies.

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Design

Ask students to test their ideas about hardness and softness. Look at a range of designs from simple to complex.

- Broadly speaking, how can we determine whether ice is hard or soft?
- How do we compare the hardness of ice to other objects?
- How practical are geologists' field tools for use in the classroom?
- What field tools might be more useful for young students?
- How ingenious are the scales created by the students?

Discuss

Hardness is an indicator of the strength of the molecular bonds maintaining the crystalline structure. When we do a scratch test, what are we scratching? What happens when we scrape and deform the ice or other object? How can we represent what happens in a model?

Use

This activity builds reasoning patterns of comparing and contrasting as well as measurement skills. Results can be displays of the hardness scales invented by the students with indications of where ice fits in.

WARM-UP AND PRE-ASSESSMENT

Words can be used in different ways—and they can have different meanings.

Lead a discussion that touches on some of the multiple meanings of words related to the topic, in the students' own words, with examples such as:

Word	Science Context	Colloquial Context
Hard	resistant to scratching	difficult
Soft	vulnerable to scratching	pliable, squeezable, cuddly
Rock	mixture of minerals	type of music
Mineral	naturally formed crystallized molecules	mixed in with vitamins to stay healthy
Fossil	ancient evidence of life found in the ground	refers to all rocks, minerals, and ores
Crystal	a regular arrangement of molecules	a fancy set of glassware
Scratch	scraping one object with another to test for hardness	what you do when you have an itch

Refer to this discussion when the words come up during the activity.

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PROCEDURES

PART 1:
Lead a discussion with the following question: How hard is hard?

Select a few very familiar objects to illustrate the following line of thinking:

When we talk *scientifically*, it becomes important to know that the words we use mean the same things to each other. For example, what do we mean by the word *hard*? Or *soft*? Are some soft things *softer* than other soft things? Could something we think of as *soft* be *harder* than something else? Could something we think of as *hard* be *softer* than something else?

Let's put things in two piles: things that are hard and things that are soft.

(Let the children say which pile an object belongs to and why.)

In the soft pile, are some things softer than others? Who would like to come up to arrange them in a row from soft to softer to softest?

And what about the hard pile? Who would like to come up to arrange them in a row from hard to harder to hardest?

Okay, when you think of ice, is it hard or soft? And why? (There may be a range of possible answers: *ice cream is soft, snow is soft, ice is hard.*)

Bring out a block of ice: is *this* ice hard or soft? If we agree that it is hard, where do you think it fits in the hard, harder, hardest arrangement that we have here?

Let's test it out. (By trial and error, place the ice where it fits.)

Now let's draw the hardness scale we have just created. Draw the objects in their order of hardness or softness.

PART 2:
Lead a discussion with the following questions:

- What is a mineral?
- What is a rock?
- How can we compare rocks and minerals?
- How does ice compare to other minerals?

The discussion introduces young students to a method of scientific understanding. A scientist may look at a particular phenomenon to learn more. We learn that there are several properties in common between ice and other minerals.

This table indicates the desired conceptual understandings.

Question	Understanding
What is a mineral?	Naturally occurring solid with a crystalline structure and a definite chemical composition
What is a rock?	A mixture of different minerals
How can we compare rocks and minerals?	We compare and contrast properties such as: hardness, brittleness, ductility, elasticity, crystalline structure, phase changes, color, luster, how it forms, and so on
How does ice compare to other minerals?	■ Occurs naturally as a solid ■ Has crystalline structure ■ Igneous: its solid form results from changing phase from liquid to solid as it cools ■ Deep glacial ice can be considered metamorphic: lower layers transformed under great pressure ■ A big difference is that it floats when surrounded by its liquid form (most rocks and minerals sink when surrounded by their liquid form)

PART 3:

Move the discussion to focus on one property, in this case, hardness, to *analyze* it in more detail. This knowledge is later *synthesized*, put back together in context with all that we know about the phenomenon, in this case, ice.

Have students create their own relative hardness scale. Instructions for students:

- Agree on a working definition of hardness as the ability of an object to resist scratching. Express in your own words
- Arrange a selection of objects (e.g., at the stations) according to their relative hardness
- Make up your own relative hardness scale (a la Mohs)
- Test how hard ice is, compared to other materials

Note: Testing materials may need to be at the same temperature as ice; for example, a warm copper penny will cause melting; a cold penny will result in scratching.

The colder the ice, the harder it is. Even at very low temperatures, the surface of ice tends to be liquid-like. When we observe ice in the classroom setting, the ice is likely to be melting. It may feel slippery to the touch and may even be described as "soft" by a young student. Be aware that we may need to discuss the block or cube of ice as a whole, as solid and hard. Melting ice softens the surface of the ice as the rising temperature breaks the hydrogen bonds.

The key is to assure that students concentrate on the nature of the phenomenon: that they perceive and express that ice is a mineral.

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DISCUSSION & REFLECTION

When you are asked to work in a group, who gets the credit for all the work?

Students are often asked to work in groups, and often without sufficient guidance regarding group dynamics. Some discussion and reflection about how to work well in a collaborative group work may lead to practical ideas about how to assure a productive learning outcome for all involved.

How important is it to keep track of your own ideas? How important is it to credit others whose ideas have inspired you?

The Mohs-Werner controversy about who originally expressed the idea of a relative hardness scale can be a springboard to discuss this important issue in science and learning.

When do we need to know how hard something is? How might we apply the notion of hardness or softness in our everyday lives?

The notion of a scientific scale of hardness or softness emerges from experiences in our everyday lives. While we might not have a formal scale, we have many situations where we judge hardness or softness.

When would you need to know about the hardness or strength of ice?

Specifically regarding ice, for example, notice that the hardness of ice before we bite into an ice cube makes a difference. Hardness is a factor for ice-skating. Notice that the strength of the ice to support weight can make a big difference.

CURRICULUM CONNECTIONS

Relative Scales

The skills that go into comparing and contrasting are useful in many aspects of life, not just science. Invite students to explore how scales are used to compare and contrast in other contexts of meaning: such as, genre of literature, art, and music.

Have some fun collecting "rock" music and rock art such as: *I am a Rock* by Simon and Garfunkel.

Invent a Game

Or invite students to create a variation of the *Red Rover, Red Rover* game that plays out the principles of hardness and the scratch test by thinking of the line of students as the surface of a rock or mineral held together by bonds of different strengths.

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ASSESSMENT CRITERIA

Exemplary

- Students ask a rich and extensive range of questions about ice as a mineral, touching on the characteristics of minerals.
- Students identify and extend science questions drawn from direct observation and extended research about ice and other minerals.
- Students write and illustrate a personal mineral and rock experience and share it dynamically with both a small group and the whole group.
- Students display observations drawn from their science notebooks with a rich display of standard and created hardness scales.
- Students observe and record a rich range of observations about ice as a mineral and relate it to prior shared experiences.
- Students make speculations and design ways to test for hardness and other characteristics of minerals.
- Students relate ideas to whole context of exploring ice in the solar system.

Emerging

- Students ask a rich range of questions about water ice and characteristics of minerals.
- Students ask basic science questions drawn from the direct observation of ice and other minerals.
- Students write and illustrate a description of direct observation of the hardness of ice, sharing it with both a small group and the whole group.
- Students observe and record a rich range of observations about the hardness of ice and other minerals.
- Student display results using techniques of using Mohs Hardness Scale or their own invented hardness scale.
- Students make speculations about possible explanations about identifying ice as a mineral.

Formative

- Students ask basic questions about the characteristics of minerals and how ice is a mineral.
- Students recognize that water ice is a mineral. Students ask basic science questions drawn out of the context of comparing ice to other minerals.
- Students succeed in observing and recording basic observations about the hardness of ice.

RESOURCES

Hardness and Mohs Hardness Scale

http://mineral.galleries.com/minerals/hardness.htm
What is important about hardness? An excellent discussion of the concept of hardness and the Mohs Hardness Scale.

http://www.windows.ucar.edu/tour/link=/earth/geology/mohs.html&edu=elem
Windows to the Universe, brief summary of Mohs Hardness Scale.

http://geology.csupomona.edu/alert/mineral/hardness.htm
NASA Project ALERT, summary of Mohs Hardness Scale.

http://gsa.confex.com/gsa/2003AM/finalprogram/abstract_60785.htm
History of Science Controversy: Who *really* created Mohs' Hardness Scale?

Ice as a Mineral

http://mineral.galleries.com/minerals/oxides/ice/ice.htm
The Mineral Ice

http://stampmin.home.att.net/ice.htm
Postage stamps showing Ice as a Mineral

http://un2sg4.unige.ch/athena/cgi-bin/minfich?s=ICE
Athena: Mineralogy

http://academic.brooklyn.cuny.edu/geology/leveson/core/linksa/hardness_def.html
City University of New York website: Very cool cartoon dialogue about hardness.

For Archimedes

http://www.andrews.edu/~calkins/math/biograph/bioarch.htm

http://www.hyperhistory.net/apwh/bios/b2archimedes_p1ab.htm

Images

Link to image gallery