Topic: Astronomy

ES-2 The student will demonstrate an understanding of the structure and properties of the universe.

Key Concepts:
Solar System: formation, properties, planets
Moon: properties & features, uniqueness
Big Bang Theory: expansion of the universe; red shift
Formation of elements: nuclear fusion; supernova
Hertzsprung-Russell diagram:
Telescopes: visual – reflecting & refracting; x-ray; radio
Life Cycle of Stars: birth, main sequence, death – supernova, black hole
Galaxies: formation & shapes, effects of gravity & motion
Technology & Computer Modeling:

ES-2.1 Summarize the properties of the solar system that support the theory of its formation along with the planets.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 4th grade (4-3.1) recalled Earth as one of many planets in the solar system. The characteristics and movements of objects in the solar system were introduced in 8th grade (8-4.1). Students have not been introduced to the theory of the formation of the solar system.

It is essential for students to know properties that are evident within the solar system that support the nebular theory of its formation. Stars and planets form from clouds of gas and dust, called interstellar clouds, that exist between the stars. This interstellar cloud material can be observed in regions along the Milky Way. The collapsing of interstellar cloud material along with its rotating motion is the beginning of the flattened rotating disk that became the solar system.

The nebular theory continues to explain the formation of the Sun and then planetesimals, many of which formed the planets. Planets near the Sun formed from elements and compounds that could withstand the Sun's heat, such as iron, and formed the terrestrial/rocky planets. The outer gas planets formed farther from the Sun where it is cool. Other remnants from solar system formation are asteroids and comets.

It is not essential for students to know physics, such as angular momentum, behind the formation process or the specific formation of the individual bodies within the solar system.

Assessment Guidelines:
The objective of this indicator is to *summarize* major points about the formation of the solar system; therefore, the primary focus of assessment should be to generalize major points about the nebular theory. However, appropriate assessments should also require students to *compare* the formation of the inner and the outer planets; *sequence* the events in the formation of the solar system; or *identify* objects that formed in the solar system.

ES-2.2 Identify properties and features of the Moon that make it unique among other moons in the solar system.
Taxonomy level: 1.1-B Remember Conceptual Knowledge

Previous/future knowledge: Students in 4th grade compared the motion and surface features of the Moon to the Sun and the Earth. They also developed an understanding of the Moon's position in relationship to Earth and the Sun. In 8th grade students summarized characteristics of the Moon, including phases, eclipses, and tides, along with other objects in the solar system. This is the first time that properties and features of the Moon, including its surface, have been studied in relation to other moons.

It is essential for students to know that the Moon as Earth's natural satellite is unique among the moons in the solar system.
Unique Properties:

Size	The Moon is one of the largest in the solar system, especially compared to the size of the planet it orbits. Also, the Moon is the only large moon among the inner planets. Mercury and Venus have no moons and the moons of Mars are just two chucks of rock.
Orbit distance	The Moon's orbit is relatively farther from Earth than most moons are from the planets they orbit.
Composition	The Moon is a solid, rocky body, in contrast to the icy composition of the moons of the outer planets.

Features:

Craters	All the craters on the Moon are impact craters.
Rays	Long trails of material (ejecta) blasted out from impacts on the Moon radiate out from craters.
Maria	These are dark, smooth plains of lower elevation on the Moon; they may contain craters and small meandering, valley-like structures.
Highlands	Cover most of the lunar surface, are mountainous, and are heavily covered with craters.
Atmosphere	The Moon has no atmosphere.

Other features of the moon due to its movement and relation to Earth are its phases and its gravitational effect causing tidal pull on Earth.

- Because of its size and the fact that the same side of the Moon always faces Earth, the illuminated side of the Moon that can be seen from Earth goes through sequential changes called phases. Students can revisit this concept as they study the unique properties and features of Earth's Moon.
- Because of its size and its close proximity to Earth, the Moon's pull of gravity creates bulges of ocean water on both the near and far sides of Earth. As Earth rotates, these bulges remain aligned with the Moon so that the ocean level rises and falls about every 12 hours. The Sun's gravitational pull also has an effect on the formation of tides, but it is about half that of the Moon.

It is not essential for students to know all the moons of the solar system or exactly how many moons each planet has.

Assessment Guidelines:
The objective of this indicator is to *identify* properties and features of the Moon; therefore, the primary focus of assessment should be to have students retrieve from memory information related to the Moon's properties and features. However, appropriate assessments should also require students to *identify* a particular features from its description; or *recall* how the Moon is unique from other moons based on a particular property.

ES-2.3 Summarize the evidence that supports the big bang theory and the expansion of the universe (including the red shift of light from distant galaxies and the cosmic background radiation).
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: The big bang theory and the expansion of the universe is a new concept for this course; it has not been presented in any previous grades.

It is essential for students to know that the big bang theory states that the universe began as a concentrated point of matter and energy that was propelled outward and has been expanding ever since. As gravity began to have an effect, galaxies formed. The galaxies continued to move outward. There is another theory, the steady-state theory, but evidence weighs in favor of the big bang. Evidence that students need to investigate includes the red shifts of galaxies and cosmic background radiation.

It is not essential for students to compare the big bang theory to other theories. An understanding of critical density and the ultimate fate of the universe based on this theory are not necessary at this time.

Assessment Guidelines:
The objective of this indicator is to *summarize* evidence that supports the big bang theory and that the universe is expanding; therefore, the primary focus of assessment should be to generalize major points concerning this evidence. However, appropriate assessments should also require students to *infer* from scientific evidence the idea that the universe is expanding; or *explain* how each piece of evidence is important to the overall theory.

ES-2.4 Explain the formation of elements that results from nuclear fusion occurring within stars or supernova explosions.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: The formation of elements as a result of nuclear fusion within stars or exploding supernovas is a new concept for this course; it has not been presented in any previous grades.

It is essential for students to have a basic understanding of the process of nuclear fusion. The temperature inside a star governs that rate of nuclear fusion. Stars in the main sequence all produce energy by fusing hydrogen into helium as the Sun does. Stars outside the main sequence may fuse different elements in their cores or may not undergo fusion at all. Once a star's core has been converted from hydrogen to helium, if the temperature is high enough, the helium may fuse to form carbon. This is the second nuclear fusion reaction phase of a star. At even higher temperatures other elements such as oxygen, neon, magnesium and silicon may form. Stars can produce few elements heavier than iron. When the outer portion of a star is blown off in a massive explosion, known as a supernova, elements heavier than iron are created and enrich the universe. The star's element composition is determined by how many fusion reaction phases it has gone through.

It is not essential for students to diagram the fusion process or write nuclear fusion equations. The comparison of nuclear fission and fusion is not part of this indicator.

Assessment Guidelines:
The objective of this indicator is to *explain* the formation of elements within stars as a result of nuclear fusion; therefore, the primary focus of assessment should be to construct cause and effect models about the formation of elements based on the fusion reaction element involved. However, appropriate assessments should also require students to *summarize* the process of nuclear fusion; *infer* how heavier elements could result from a supernova explosion; *recall* elements formed from nuclear fusion in stars; or *identify* the elements formed in the first two fusion reaction phases.

ES-2.5 Classify stars by using the Hertzsprung-Russell diagram.
Taxonomy level: 2.3-B Understand Conceptual Knowledge

Previous/future knowledge: The Hertzsprung-Russell diagram and its use as a classification tool for stars is a new concept for this course; it has not been presented in any previous grades.

It is essential for students to know that the properties of mass, magnitude/brightness, temperature and diameter of stars are closely related. This relationship has been shown on a chart known as the Hertzsprung-Russell diagram (H-R diagram).

Absolute magnitude	This property of brightness is plotted on the vertical axis of the chart.
Spectral type	This property is found on the lower horizontal axis. Stars are given a letter and number based on the pattern of spectral lines produced by the star and temperature. O stars being the hottest and M stars being the coolest.
Surface temperature	Measured in Kelvin is located along the top horizontal axis. Highest temperatures are on the left to coolest temperatures on the right.

Students will need to use these properties on the axes of the chart to classify stars.

Main sequence	90% of stars, including the Sun, are found along a diagonal that runs from the upper left where hot, bright stars are found to the lower right where cool, dim stars are found. All these stars have similar internal structures and functions.
Giants	These stars are found in the upper right of the chart. They are cool stars with large surface areas that are bright, so they are called red giants.
Dwarfs	Dim, hot stars are plotted in the lower left corner. They are small or they would be brighter. These are called white dwarfs.

It is not essential for students to classify individually named stars, but understanding the meaning of the placement of a star on the chart is necessary.

Assessment Guidelines:
The objective of this indicator is to *classify* stars through the use of the Hertzsprung-Russell diagram; therefore, the primary focus of assessment should be to place stars into a classification according to the properties shown on the diagram. However, appropriate assessments should also require students to *interpret* the chart as to the meaning of the factors on the horizontal and vertical axes; *exemplify* stars found in various locations on the chart; or *identify* the classification of the Sun based on the H-R diagram.

ES-2.6 Compare the information obtained through the use of x-ray, radio, and visual (reflecting and refracting) telescopes.
Taxonomy level: 2.6-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 4th grade were introduced to the telescope as a tool of astronomers. In 8th grade students compared the purpose of tools and technology that scientists use, including the telescope, but not the structure of telescopes. In Earth Science students will now compare specific telescopes in order to determine the information that can be gathered from each type.

It is essential for students to know that x-ray, radio, and visual telescopes are each constructed in such as way as to allow information to be gathered regarding objects and events in the universe. Objects in space emit radiation in all frequencies of the electromagnetic spectrum. Some of the wavelengths the human eye cannot detect so a variety of telescopes have been developed. The goal of all telescopes is to bring as much radiation as possible to a focus.

X-ray Telescopes

- Since x-rays cannot be easily reflected by any surface, a special design for detecting x-rays had to be developed.
- An arrangement of cylindrical mirrors allows X-rays to be guided to a precise focus to form an image.

Visual Telescopes

Reflecting

- Uses a concave mirror instead of an objective lens to focus a large amount of light onto a small area; the larger the mirror, the more light the telescope can collect;
- A flat mirror reflects the light to the eyepiece lens.
- The majority of visual telescopes used today are reflecting.

Refracting

- Uses convex lenses to bring visible light to a focus;
- The largest lens is called the objective lens; the second lens is the eyepiece lens;
- When light passes through the objective lens, the lens focuses the light at a certain distance away from the lens; the larger the objective lens, the more light it can collect.

Radio Telescopes

- Most radio telescopes have curved, reflecting surfaces that are used to detect radio waves from object in space;
- The surface of the telescope concentrates faint radio waves onto small antennas.

It is not essential for students to use ray diagrams to trace the path of incoming radiation into the various telescopes. It is not necessary for a complete study of the Hubble Space telescope to be part of this indicator, but it may make an interesting additional study.

Assessment Guidelines:
The objective of this indicator is to *compare* information gathered from types of telescopes; therefore, the primary focus of assessment should be to detect ways that these instruments are alike or different in regards to the collection of information from space. However, appropriate assessments should also require students to *interpret* diagrams that show how a telescope collects information; *compare* the visual reflecting and refracting telescopes; or *identify* a telescope based on a description of the information it is able to collect.

ES-2.7 Summarize the life cycles of stars.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: The life cycle of stars is new material for this course.

It is essential for students to know that the life cycle of a star depends on its mass.

Birth of a Star

- All stars begin their lives as parts of nebulas.
- A protostar is the earliest stage of a star's life.
- A star is born when the contracting gas and dust become so hot that nuclear fusion starts.

Life of a Star

Main-Sequence stars

- The second and longest stage in a main-sequence star's life cycle takes place while the star has an ample supply of hydrogen to fuse into helium;
- When the hydrogen has fused into helium, the core of the star contracts and the outer shell expands greatly; it has become a giant star.

Massive stars

- Have many shells fusing different elements; as more shells are formed, the star expands to a larger size and becomes a supergiant star;
- The star is very luminous and uses up it fuel quickly;

Death of a Star

- When a star runs out of fuel, its core no longer releases energy, it becomes a white dwarf, a neutron star, or a black hole;
- Giants that have had their outer parts drift out into space, leave behind the blue-white hot core – a white dwarf;
- A dying supergiant star can suddenly explode; the explosion is called a supernova; material that is left behind forms a neutron star.
- The remains of the most massive stars collapse into black holes; not even light can escape from a black hole.

It is not essential for students to know the internal dynamics of what goes on within the star at the various stages of life. Temperature data and life cycle time should be relative terms.
Time permitting, some basic study of constellation may spark student's interest, but it is not essential.

Assessment Guidelines:
The objective of this indicator is to *summarize* the life cycle of stars; therefore, the primary focus of assessment should be to generalize major points about the birth, life and death of stars. However, appropriate assessments should also require students to *interpret* diagrams that show varying aspects of a star's life cycle; *compare* the life cycles of stars of different mass; or *recall* the possibilities that could occur at the death of a star.

ES-2.8 Explain how gravity and motion affect the formation and shapes of galaxies (including the Milky Way).
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Galaxies and their shapes were introduced in 8th grade (3-3.8). In this course understanding of the factors that influence the formation and the shapes of those galaxies are developed.

It is essential for students to know that the major components of the universe are galaxies consisting of groups of stars bound together by gravitational attraction. Galaxy formation theory is just beginning to be developed. The present view of galaxy formation holds that large systems were build up from smaller ones through collisions and mergers. Galaxies are classified by shape into three main types – spiral (normal and barred), elliptical, and irregular.

Spiral Galaxies:
- Contain a flattened galactic disk in which the spiral arms are found, a central galactic bulge, and a halo of faint, old stars.
- The galaxy contains both young and old stars along with gas and dust that continue formation of new stars.
- The Milky Way galaxy that contains our solar system is a spiral galaxy; it looks milky or hazy because the stars are to close together to for human eyes to see them individually.
- The gas and stars in the disk move in circular orbits around the galactic center.

Elliptical Galaxies:
- Have no galactic disk; stars are distributed throughout the nearly spherical to very flattened shape.
- There are no obvious structures other than a dense central nucleus/
- The galaxy contains only old stars along with little or no gas and dust for new star formation.
- The stars in the galaxy move in random orbits.

Irregular Galaxies:
- Have no obvious structure; some have an explosive appearance.
- The galaxy contains both young and old stars with ongoing star formation.
- The gas and stars in the disk move in very irregular orbits.

It is not essential for students to know the names of specific galaxies other than the Milky Way or the further classifications within the main three. Distances between galaxies, galaxy clusters, or properties of galaxies are also not essential content for this indicator.

Assessment Guidelines:
The objective of this indicator is to *explain* the formation of galaxies and shapes of galaxies based on gravity and motion; therefore, the primary focus of assessment should be to develop cause and effect models of these concepts. However, appropriate assessments should also require students to *illustrate* the shapes of galaxies; *compare* the three types of galaxies by description, star formation, and movement of galaxy gas and dust; or *recognize* the basic components of each type of galaxy.

ES-2.9 Explain how technology and computer modeling have increased our understanding of the universe.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade explained how telescopes, space probes, and satellites have been used to explore the solar system. Obtaining information beyond the solar system out into the stars and galaxies is new material for this course.

It is essential for students to know that with the development of increasingly more sensitive and sophisticated instruments, scientists are able to collect information farther and farther into the universe. Along with telescopes, devices that now collect millions of pixels of light can store the data on a disk or tape for image processing. A wide variety of non-optical telescopes and space-based observatories allow astronomers to probe regions of space that give off little or no visible light and to study many objects that emit little or no optical radiation at all. Upon gathering this information, computer programs can enhance the information to create images that help to unlock some of the mysteries hidden in the universe.

Assessment Guidelines:
The objective of this indicator is to *explain* how technology and computer modeling help to increase understanding of the universe; therefore, the primary focus of assessment should be to construct cause and effect models that show how this technology is helping in the study of the universe within and outside of our solar system. However, appropriate assessments should also require students to *identify* types of technology that have been developed; or *infer* how our perceptions of the universe have changed due to this technology.

Topic: Solid Earth
ES-3 The student will demonstrate an understanding of the internal and external dynamics of solid Earth.

Key Concepts:
Origin-Formation of Earth's Systems: gravitational force, heat production; nebular theory
Earth's Layers: core – inner & outer; mantle – lithosphere, asthenosphere, crust
Theory of Plate Tectonics: convection currents; plate boundaries; scientific evidence
Crustal changes: earthquake activity; volcanic eruptions; mountain building
Geologic processes: weathering, erosion, deposition, glaciation
Rock Cycle: divisions of the rock cycle; processes that form types of rocks
Mineral & Rock classification: properties of mineral & rocks;
Ores: formation
Fossil fuels: formation – coal, petroleum, natural gas; environmental impact

ES-3.1 Summarize the theories and evidence of the origin and formation of Earth's systems by using the concepts of gravitational force and heat production.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that according to the nebular theory (gravitational condensation theory), Earth was formed as a planet in the solar system from material in the solar nebula that condensed and compacted due to gravitation force. Shortly after Earth formed, the decay of radioactive elements and the heat released by colliding particles produced some melting of the rocky material that made up Earth. The denser elements, mainly iron and nickel, sank due to gravity to Earth's center, while the lighter, rocky components floated outward toward the surface. This sorting of material by density is believed to be continuing on a smaller scale even today. Gaseous materials were allowed to escape from Earth's interior. By this process an atmosphere gradually formed, composed chiefly of gases expelled from within the planet. Other theories include the planetesimal theory and the tidal theory.

Earth's systems are today powered by energy from the Sun and also from Earth's internal heat. After the formation of the atmosphere and hydrosphere, the Sun's energy drives the systems in the atmosphere, hydrosphere, and at Earth's surface. Heat remaining from when Earth formed and that is continuously generated by the decay of radioactive elements powers the internal processes that produce volcanoes, earthquakes, and mountains.

It is not essential for students to know the details of other theories that do not involve gravitational force and heat production.

Assessment Guidelines:
The objective of this indicator is to *summarize* major points about the formation of Earth; therefore, the primary focus of assessment should be to generalize major points about the nebular theory as it relates to gravitational force and heat production. However, appropriate assessments should also require students to *compare* the formation of Earth based on various theories; *sequence* the events in the formation of Earth; or *compare* material that makes up the core with that found in the crust.

ES-3.2 Explain the differentiation of the structure of Earth's layers into a core, mantle, and crust based on the production of internal heat from the decay of isotopes and the role of gravitational energy.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade (8-3.1) understood the structure of the layers of Earth on the basis of position, density, and composition. Students have not been introduced to the reasons for this differentiation of internal structure.

It is essential for students to know that the layering of Earth into core, mantle and crust occurred early in Earth's formation because the temperature within the planet steadily increased due to decay of radioactive elements. Earth became so hot that at least some melting of original materials occurred and denser materials were pulled to the core. Heat from the core and radioactivity within the mantle keep the mantle hot. The gradual increase in temperature and pressure within Earth affects the physical properties and the mechanical behavior of Earth materials. Therefore, depending upon the temperature and pressure, a particular Earth material may behave like a solid, or like a puttylike material, or even melt and become a liquid in various Earth layers.

Core: The heavier material sank to become the core. At the extreme pressures found in the core, the iron-rich material becomes very dense. The solid inner core and the liquid outer core make up nearly one third of Earth's mass. The convective flow of metallic iron in the outer core generates Earth's magnetic field. Despite its high temperature, the material in the inner core under immense pressure behaves like a solid.

Mantle: The mantle is a zone of rock that makes up almost two-thirds of Earth's mass. It is divided into different regions – the top portion, along with the crust, is mostly igneous rock and is part of the *lithosphere*. The *asthenosphere*, below the lithosphere, is partially melted due to increases in pressure and temperature. In the lower mantle pressure increases and the rock material strengthens to a more rigid layer. Even so, the rocks are still hot and capable of very gradual flow.

Crust: Earth's outermost layer is the crust, a relatively cool, rigid shell. It makes up only about one percent of Earth's mass. There are two types of crustal material – oceanic crust and continental crust.

The behavior of seismic waves has allowed scientists to learn much about Earth's interior structure.

It is not essential for students to know the temperatures or distances for each of the layers.

Assessment Guidelines:
The objective of this indicator is to *explain* the structure of Earth 's layers; therefore, the primary focus of assessment should be to construct cause and effect models of how the production of internal heat and the role of gravitational energy effect the structure of Earth's crust, mantle, and core. However, appropriate assessments should also require students to *compare* the layers of Earth; *sequence* the layers; or *identify* the layers or sub-layers based on properties.

ES-3.3 Summarize the theory of plate tectonics (including the role of convection currents, the action at plate boundaries, and the scientific evidence for the theory).
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade (8-3.6) were introduced to the theory of plate tectonics with the motion of the lithospheric plates and geologic activities at the plate boundaries. Students have not been introduced to the internal driving forces or to the scientific evidence for the theory.

It is essential for students to know the theory of plate tectonics states that Earth's crust and rigid upper mantle are broken into enormous sections called plates. Tectonic plates move in different directions and at different rates over Earth's surface. The plates are continually changing in shape and size.

What causes Earth's plates to move is explained in a hypothesis that proposes convection currents within the mantle.

Role of Convection Currents:

The movement of the plates is driven by the unequal distribution of heat within Earth that set up convection currents within the upper mantle. Hot material found deep in the mantle moves slowly upward and serves as one part of Earth's internal convection system. Also cooler, denser sections of oceanic lithosphere descend into the mantle, setting the outer crust into motion. Convection currents in the asthenosphere are thus set in motion by the transfer of energy between Earth's hot interior and the cooler exterior. There are still many unanswered questions about mantle convection currents.

When tectonic plates move, they interact at places called plate boundaries. Each type of boundary has certain geologic characteristics and processes associated with it.

Action at Plate Boundaries:

Divergent Boundaries: Places where two plates are moving apart (separating) are called divergent boundaries. Most are found on the sea floor and form ocean ridges. The formation of new crust occurs at most divergent boundaries and accounts for high heat flow, volcanic eruptions, and earthquakes. On continents when continental crust begins to separate, the stretched crust forms a long, narrow depression called a rift valley.

Convergent Boundaries: Places where two plates are moving toward each other are called convergent boundaries. There are three types, which are classified by the type and density of crust involved: (1) Oceanic crust converging with oceanic crust – one of the two plates becomes denser due to cooling and descends beneath the other in a process called subduction that creates a deep trench and a volcanic arc of islands. The subducted plate descends into the mantle and melts, thus recycling the crustal material. (2) Oceanic crust converging with less dense continental crust – subduction also occurs but the subduction causes a trench and a mountain range with many volcanoes along the continent's edge. (3) Continental plates collide – both plates are too buoyant to be subducted, so the colliding edges of the continents are crumpled and uplifted to form a mountain range.

Transform Boundaries: Places where two plates slide horizontally past each other are called transform boundaries. at these boundaries crust is only deformed or fractured. Most transform boundaries are not found on continents; a famous exception is the San Andreas Fault in southwest California.

Evidence for the plate tectonic theory began with early observations made about the shape of the continents. A continental drift hypothesis was developed. Evidence for this hypothesis included similar rock types and formations on continents now separated, as well as similar fossils of several different animals and plants that once lived on land now found to be widely separated continents. That hypothesis was originally rejected because the force great enough to move continents could not be shown but as more evidence was gathered it was revisited and leads to today's plate tectonics theory. In the 1960s evidence was found on the seafloor that could explain how continents move.

***Scientific evidence for the Theory**:*

Seafloor spreading: This theory states that new ocean crust is formed at ocean ridges where magma rises to the surface and hardens; a new section of crust forms which slowly moves away from the ridge. Crust is destroyed, remelted, at deep-sea trenches.

Magnetic striping: As scientists collected data about the areas parallel to the ocean ridges, magnetic patterns emerged. The magnetic pattern on one side of the ridge matched the pattern on the other. Scientists were able to determine the age of the ocean floor from the magnetic recording. Relatively you ocean floor crust is found near ocean ridges and older ocean crust is found along deep-sea trenches.

Even though it is not specifically stated in the indicator, a knowledge of some of the major plates, their locations, and relative motion helps students to identify plate boundaries and the formations and activities that are evident along the plate boundary in that region of Earth.

It is not essential for students to know the explorations that took place to acquire the information for the theory of plate tectonics.

Assessment Guidelines:

The objective of this indicator is to *summarize* major points about the theory of plate tectonics; therefore, the primary focus of assessment should be to generalize major points about the role of convection currents, the actions at plate boundaries, and evidence for the theory. However, appropriate assessments should also require students to *compare* the actions at the various plate boundaries; *illustrate* with drawings or diagrams the geologic characteristics and processes at plate boundaries; or *recall* evidence from the early continental drift hypothesis.

ES-3.4 Explain how forces due to plate tectonics cause crustal changes as evidenced in earthquake activity, volcanic eruptions, and mountain building.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade (8-3.7) illustrated the creation and changing of landforms due to volcanic eruptions and mountain-building forces but it was not necessarily tied to the forces due to plate tectonics.

It is essential for students to know that many crustal changes occur because of the forces interact at and within plate boundaries.

- Where forces on the plates are pulling them apart, new crustal material forms as volcanic eruptions bring magma up to the surface; earthquakes often accompany a volcanic eruption. Undersea mountain ridges are built from this activity as magma cools and hardens.
- At converging boundaries the force of plates being pushed together may form deep undersea trenches; volcanic eruptions occur as some magma is forced back to the surface to form either volcanic arcs or volcanoes within mountain ranges. Converging forces may slowly push continental crust against continental crust so that the land crumples and folds to form a mountain range.
- As plates slide past each other along transform fault boundaries, the build up of pressure along the boundary may cause the fault to quickly move resulting in an earthquake.
- Some volcanoes are located far from plate boundaries in regions known as *hot spots*. These are formed where high-temperature mantle material rises toward the surface in plumes that melt crustal rock turning it to magma. The magma melts through the crust to form volcanoes. A trail of older volcanoes forms as a plate moves over a hot spot, such as the Hawaiian Islands. Chains of volcanoes that form over hot spots provide important information about plate motions, such as rate and direction. Students may find the study of the hot spot beneath the Yellowstone Basin in Wyoming an interesting study.

It is not essential for students to know about forces that cause crustal change and activities within tectonic plates.

Assessment Guidelines:
The objective of this indicator is to *explain* crustal changes due to the forces of plate tectonics; therefore, the primary focus of assessment should be to construct cause and effect models of how tectonic forces could result in earthquake activity, or volcanic eruptions, or mountain building. However, appropriate assessments should also require students to *interpret illustration* to determine the cause of the feature; or *summarize* activities that occur to Earth's crust because of plate tectonic forces.

ES-3.5 Analyze surface features of Earth in order to identify geologic processes (including weathering, erosion, deposition, and glaciation) that are likely to have been responsible for their formation.
Taxonomy level: 4-B Analyze Conceptual Knowledge

Previous/future knowledge: Students in 5th grade (5-3.1) explain how natural processes of weather erosion, and deposition affect Earth's oceans and land in constructive and destructive ways. In 8th grade (8-3.9) students identified and illustrated geologic features as viewed using imagery and topographic maps. Students have not been introduced the process of glaciation nor its resulting features.

It is essential for students to use illustrations, imagery, topographic maps, pictures, or descriptions of surface features to determine geologic processes responsible for those features.

Weathering: This process includes both the disintegration and decomposition of surface rock material. *Disintegration* is the physical or mechanical breakdown of Earth materials; the original material has not changed, just its size or shape. Rocks may be cracked, broken, or peeled off through mechanical weathering. Decomposition is the chemical altering of the composition of the material. Acids, water, carbon dioxide, or oxygen may react with the rock material causing the change.

Erosion: This process moves weathered material from one place to another. Various erosional agents (gravity, wind, water, plants/animal/humans) pick up Earth materials and carry them to other locations. Erosion is a destructive process that wears down Earth's surface, Gullies, rills, changes in coastal topography, sand dunes, and landslides are evidence of erosion by those various agents.

Deposition: This process is closely related with erosion because they are dependent on one another. The agent that eroded the material in one place will deposit it in another. It is a constructive process that builds up Earth's surface. Deltas and sandbars or barrier islands are a result of deposition.

Glaciation: This process has the capacity to carry huge rocks and piles of debris over graet distances. Glaciers scrape and gouge out large sections of Earth's landscape. Features left in the wake of glaciation include U-shaped valleys, waterfalls, glacial lakes, and various types of deposits such as moraines.

It is not essential for students to know the names for individual processes of weathering, erosion, or glaciation – just the broad concepts.

Assessment Guidelines:
The objective of this indicator is to *analyze* surface features of Earth to identify the geologic processes responsible for their formation; therefore, the primary focus of assessment should be to determine from material presented the relevant information that would determine the cause for a particular geologic feature or the change that occurred to a geologic feature. However, appropriate assessments should also require students to *compare* the processes of weathering, erosion, and deposition; *summarize* the processes that change the surface features of Earth; or *identify* features of glaciation.

ES-3.6 Explain how the dynamic nature of the rock cycle accounts for the interrelationships among igneous, sedimentary, and metamorphic rocks.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade (8-3.4) explained how types of rocks were interrelated using the rock cycle. Students in Earth Science need to expand on the basic process to show interrelationships by the processes that act upon and within the planet.

It is essential for students to know that the rock cycle illustrates the continuous changing and remaking of rocks on Earth. The rocks of Earth, whether they are at the surface or below the crust, are always positioned somewhere on the rock cycle. The three types of rock – igneous, sedimentary, and metamorphic – are grouped according to how they form. These rock types form the divisions of the rock cycle. Processes can change any rock into another rock. Internal processes include heat & pressure, melting, cooling & crystallization; and uplift. External processes include weathering, erosion, deposition, burial, and lithification. There is more than one path in the rock cycle; that's its dynamics.

Assessment Guidelines:
The objective of this indicator is to *explain* the dynamic nature of the rock cycle; therefore, the primary focus of assessment should be to construct cause and effect models of how surface and internal processes account for formation, change and reforming of rocks on Earth. However, appropriate assessments should also require students to *compare* the processes that could form or change each type of rock; *recognize* internal and external processes that change rocks; *or identify* a type of rock by the process that formed it.

ES-3.7 Classify minerals and rocks on the basis of their physical and chemical properties and the environment in which they were formed.
Taxonomy level: 2.3-B,C Understand Conceptual-Procedural Knowledge

Previous/future knowledge: Students in 3rd grade (3-3.1) classified rocks into one of the three types based on physical properties and identified minerals (3-3.2) by properties on an identification key. In 8th grade (8-3.4) the three rocks types were explained through the rock cycle and the importance of minerals (8-3.5) summarized based on physical and chemical properties. Students have not classified mineral or rocks using an identification process.

It is essential for students to know the processes and properties that allow for mineral identification and rock identification. They should be able to use mineral and rock identification keys/charts.

Mineral Identification:
Geologists rely on several relatively simple tests to identify minerals. These tests are based upon a mineral's physical and chemical properties. By using the results from a combination of tests rather than just one, the mineral's classification and identity is more accurate. Comparing test results from the mineral sample with known properties of minerals from a mineral identification chart increases the accuracy of the identification.
Mineral identification properties and tests students should be able to perform include:

- color, luster, texture, streak, hardness, and cleavage & fracture.
- Density tests may also be performed if the right equipment is available. Heft (heaviness compared to sample size) is sometimes used as a relative density description.
- Some minerals have special properties that are useful in identification, such as reaction with acid, magnetic attraction, or light refraction in transparent or translucent minerals.

Rock Identification:
Rocks are made up of minerals and are formed very differently, therefore their identification and classification is fairly complicated. Geologists must analyze mineral composition, evidence of type of formation, and size & arrangement of minerals to determine the classification of rocks. After basic information is gathered on a specific rock to determine its major rock type and classification, properties on a rock identification chart can be used to identify the specific rock sample.
Rock identification properties and tests students should be able to perform include:

- For *igneous* rocks – determine if the igneous rock is *intrusive* or *extrusive* based on - texture (fine-grained, coarse grained, glassy crystal size); composition of minerals (using common minerals such as quartz, feldspar, mica, hornblende).
- For *metamorphic* rocks – determine if the metamorphic rock is *foliated* or *nonfoliated* based on – texture (layers or bands of minerals, not banded); coarse-grained or fine-grained
- For *sedimentary* rocks – determine if the sedimentary rock is *clastic*, *organic*, or *chemical* based on – evidence of sediment particles/grains (coarse-grained, medium-grained, fine-grained) cemented together; evidence of once-living material (shells, plants/carbon,); evidence that the material could have been precipitated or settled out of water or was evaporated from solution.

The properties of the rocks also give clues to the environment in which they were formed.

- Intrusive igneous rocks with their larger crystals were formed deep inside Earth where slow cooling could take place. Small grained or glassy texture of extrusive igneous rocks indicates rapid cooling at Earth's surface with little to no time for crystals to grow.
- The grade of metamorphic rock is dependent upon a combination of factors including pressure on the rocks, the temperature, and the depth below the surface.
- Clastic sedimentary rocks with particles that are rounded are evidence of water transported materials while angular fragments indicated little transport or possibly wind born.
- Changes in river level or sea level may result in stratification of sedimentary rock layers.

It is not essential for students to do further classification of minerals into groups/families or to identify specific mineral crystal systems. The composition or origin of magma or the process of crystallization is not essential, although students may find crystal growing an interesting activity. Further classification of igneous, metamorphic, or sedimentary rocks beyond the main grouping is not necessary.

Assessment Guidelines:
The objective of this indicator is to *classify* minerals and rocks; therefore, the primary focus of assessment should be to use physical and chemical properties of minerals and of rocks to determine which category the sample belongs and also the environment in which it was formed. However, appropriate assessments should also require students to *identify* a mineral property based on its description; *explain* how the formation environment affects crystal size or grain texture; or *interpret* information on a mineral or rock identification chart.

ES-3.8 Summarize the formation of ores and fossil fuels and the impact on the environment that the use of these fuels has had.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade (8-3.5) summarized the importance of ores and fossil fuels because of their physical and chemical properties. Students have not been introduced to how these materials formed nor to the impact their use has had on the environment.

It is essential for students to know how ores and fossil fuels form.

Ore formation: A metal element or mineral is an *ore* if it contains a useful substance that can be mined at a profit. Ores form within Earth's crust as magma cools. Dense metallic minerals sink to the bottom of a body of magma. Layers of minerals accumulate and form ore deposits within the hardened magma. Hot mineral solutions may also spread through small cracks in rock and harden in fingerlike bands called veins or lodes.

Fossil fuel Formation: Because of their organic origin, coal, petroleum, and natural gas are called *fossil fuels*. *Coal* is a dark-colored organic rock formed from the remains of plants that flourished millions of years ago. Usually dead plants decompose, but if oxygen in a swamp area is limited and decay rate is slow, the compressed organic matter becomes coal. *Petroleum* and *natural gas* originated with once living organisms that died and their remains accumulated on the ocean floor and lake bottoms, buried by sediments. As with coal, limited oxygen prevented the remains from decomposing completely. As more and more sediments accumulated, heat and pressure increased becoming great enough to convert the remains into petroleum and natural gas.

Fossil fuels, like minerals, are nonrenewable resources that are needed in our world today, but the obtaining and use of these fuels can have an impact on the environment:

- Coal is the most abundant fossil fuel in the world. The present reserves of coal should last about 200 years. Anthracite coal is the most efficient, cleanest burning coal, but it has the smallest reserves. Most coal burned is bituminous that releases carbon, sulfur, and nitrogen oxides into the air causing air pollution and acid precipitation, so safeguards are important to keep the abundance of these oxides from the air. Strip mining of coal leaves deep ditches where the coal is removed, so mining companies work to ensure that the land around the mine is reclaimed as close to its natural state as possible.
- Petroleum production involves looking for oil traps in folds of the rock layers or in fracture or fault zones. Oil shale also contains petroleum between its layers, but the cost is great to mine it. Transporting of oil must also be done with care so that oil spills from tankers and pipelines do not pollute ocean waters or harm wildlife.

Assessment Guidelines:
The objective of this indicator is to *summarize* the formation of ores and fossil fuels and also to *summarize* the impact these fuels have had on the environment; therefore, the primary focus of assessment should be to generalize the major points about the formation of ores and fossil fuels and environmental impact issues regarding the use of fossil fuels. However, appropriate assessments should also require students to *exemplify* (give examples of) ways that fossil fuels impact the environment; or *identify* the types of fossil fuels.

Topic: Earth's Atmosphere

ES-4 The student will demonstrate an understanding of the dynamics of Earth's atmosphere.

Key Concepts:
Atmosphere: structure (troposphere, stratosphere, mesosphere, thermosphere, exosphere), gas composition - ozone; thermal changes (tropopause, stratopause)
Convection cells: tropical, temperate, polar
Climate influences: latitude, topography, elevation, water proximity
Wind belts: trade winds, westerly winds, polar winds
Global climate change: ice ages, interglacial period, El Nino
Weather: air masses, high and low pressure systems, frontal boundaries
Storms: thunderstorms, hurricanes, tornadoes

ES-4.1 Summarize the thermal structures, the gaseous composition, and the location of the layers of Earth's atmosphere.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have encountered a study of moving "air" in 2nd and 4th grade and a study of gases in 3rd grade. Students were introduced to the concept of Earth's atmosphere and layers in 6th grade (6-4.1). This study included the identification of the layers; the gas composition within the layers, and differences in temperature within the layers. In Earth Science these concepts are revisited as students develop an understanding of the complexity of Earth's atmosphere.

It is essential for students to know that Earth's *atmosphere* is the layer of gases that surrounds the planet and makes conditions on Earth suitable for living things. It is a mixture of chemical elements and compounds differentiated by distinct differences in temperature with increasing altitude. This thermal structure differentiates the layers:

Atmospheric Temperatures	Differences in temperature separate the layers.	• As altitude increases, temperature decreases in the *troposphere*; at the upper boundary, the *tropopause*, temperatures stop decreasing • The *stratosphere* is cold except in its upper region where ozone is located; high temperature zone, called the *stratopause*, marks the upper boundary • The *mesosphere* is the coldest layer; temperature decreases as altitude increases • Even though the air is thin in the *thermosphere*, it is very hot; temperature increases as altitude increases • The cold regions of outer space extend from the *exosphere*
Atmospheric Layers Earth's Surface ↓ Space	Earth's atmosphere is divided into several different *atmospheric layers* extending from Earth's surface outward:	• the *troposphere*, where all weather occurs • the *stratosphere*, where the ozone layer is contained • the *mesosphere* • the *thermosphere* • the *exosphere*

Atmospheric Gases	Nitrogen (N_2) and Oxygen (O_2)	• the two most common gases; found throughout all the layers
	Ozone (O_3)	• a form of oxygen found in the stratosphere; in the upper atmosphere protects Earth's inhabitants from harmful ultraviolet rays of the Sun
	Water vapor (H_2O) and carbon dioxide (CO_2)	• most important compounds in the atmosphere; important gases for weather conditions; found in the troposphere
	Trace gases, for example argon	• play an insignificant role

It is not essential for students to know the exact distance between each layer or the specific temperatures of the layers, or how the oxygen-carbon dioxide cycle and nitrogen cycle maintain stable amounts of those gases in the atmosphere. They do not need to compare the properties of pure air with air containing particulate matter and unnatural gases, polluted air, although this discussion would be interesting to increase the understanding of the effects of contaminants on pure air.

Assessment Guidelines:
The objective of this indicator is to *summarize* major points about the layers of Earth's atmosphere; therefore, the primary focus of assessment should be to generalize major points about the temperature differentiation in the layers, the gas composition of the layers, and the location of the layers in respect to Earth. However, appropriate assessments should also require students to *compare* one layer to another; *sequence* the layers from Earth outward; or *recall* gasses that are found in the atmosphere as to abundance and importance.

ES-4.2 Summarize the changes in Earth's atmosphere over geologic time (including the importance of photosynthesizing organisms to the atmosphere).
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concept in this indicator in any previous grade.

It is essential for students to know that Earth's early atmosphere was probably composed mainly of methane and ammonia. In the early forming of Earth, its surface was much more volcanically active than it is today. Earth's primitive atmosphere changed as erupting volcanoes emitted gasses such as water vapor, chlorine, carbon dioxide, hydrogen, and nitrogen. As the planet cooled, the water vapor condensed and absorbed most of the carbon dioxide; rains began to fall. Oxygen was probably formed from the breaking down of water molecules and also by photosynthesis of primitive cyanobacteria. Large mats and mounds of billions of cyanobacteria dominated the shallow oceans of Precambrian Earth. These organisms generated large amounts of oxygen, some of which also formed ozone, which, in turn, filtered out UV radiation so that other forms of life could survive on Earth's surface. As it appears, nearly all the oxygen that living things breathe today, and the oxygen that all animals have breathed in the geologic past, was released into the atmosphere primarily by photosynthesis.

It is not essential for students to know the details of photosynthesis or the processes by which volcanoes produce and spew gases during eruptions. An understanding of the evidence geologists have found in regards to early Earth's atmosphere is interesting but not essential.

Assessment Guidelines:
The objective of this indicator is to *summarize* the changes that have occurred to Earth's atmosphere over time; therefore, the primary focus of assessment should be to generalize major points about these changes and their causes, including the role of photosynthesizing organisms. However, appropriate assessments should also require students to *compare* the atmosphere of Earth today with Earth's earlier atmospheres; or *identify* causes of change to Earth's atmosphere.

ES-4.3 Summarize the cause and effects of convection within Earth's atmosphere.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to the concepts in this indicator in 6th grade (6-4.8). This study included explaining how convection affects weather patterns and climate. In Earth Science students will develop concept of the cause of convection within the atmosphere.

It is essential for students to know that convection is the transfer of heat energy in fluids, liquids or gases, by the movement of the heated particles. In convection, particles with higher energy move from one location to another carrying their energy with them. Particles with the higher energy move from warmer to cooler parts of the fluid. Because of Earth's spherical shape, the Sun's rays strike Earth more directly at the tropics than they do at the poles. At the poles, the same amount of solar radiation is spread over a larger area than at the equator. This unequal heating sets up the warmer-cooler regions necessary for global convection to take place in the atmosphere.

The air flowing from the equator completes three looping patterns of flow called *convection cells*. There are three atmospheric convection cells in the northern hemisphere and three in the southern hemisphere.

- the *tropical convection region* begins at the equator and extends to the about 30 degrees north or south latitude – warm air rises at the equator then cools enough to descend at about 30 degrees latitude from which air flows both north and south;
- the *temperate convection region* extends from there to about 60 degrees north or south latitude – descending air moves either back toward the equator or toward the poles where the air at about 60 degrees and warmed enough to create a low pressure area and again rise;
- the *polar convection region* extends from there to the poles, 90 degrees north or south latitude – air at the poles is descending cold air that moves toward the equator; at about 60 degrees it has warmed enough to begin rising.

Students should understand convection on a global scale in the atmosphere, which causes global winds, and therefore is the mover of weather systems in particular directions.

- Due to the spinning of Earth, the weather systems in these convection cells move in certain directions because the *global wind belts* are set up (ES-4.5).
- On a smaller scale, convection currents near bodies of water or near mountains can cause local winds known as *land and sea breezes* or *mountain and valley breezes*.

Because of the unequal heating of Earth, *climate* zones (tropical, temperate, and polar) also occur.

- Since temperature is a major factor in climate zones, students should relate climate to the convection regions at various latitudes, to temperature differences between the equator and the poles, and also to warm and cold surface ocean currents.

It is not essential for students to know the cause and effects of radiation (other than the angle of solar radiation) and conduction on the atmosphere. This indicator is not a complete study on the conditions related to climate. Climate is only related as an effect of global convection.

Assessment Guidelines:
The objective of this indicator is to *summarize* the cause and effects of convection; therefore, the primary focus of assessment should be to generalize major points about how convection cells are caused and their effects within the atmosphere. However, appropriate assessments should also require students to *interpret* diagrams of convection cells; *explain* how the angle of solar radiation affects heating of Earth; or *compare* convection regions to the global wind belts.

ES-4.4 Attribute global climate patterns to geographic influences (including latitude, topography, elevation, and proximity to water).
Taxonomy level: 4.3-B Analyze Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that climate is referred to as the average weather conditions of a region, the weather patterns that occur over many years. Scientists usually describe it in terms of the average monthly and yearly temperatures, or temperature range, and the average amount of precipitation. Other factors also influence the temperature and precipitation of a climate region:

Latitude A major influence on the climate of a region is its distance from the equator – *latitude*. Latitude determines the amount of solar energy received by, and the prevailing wind belts of, the region. Climate zones based on latitude include tropical climates, middle-latitude climates, and polar climates.

Topography & Elevation The shape of the land, *topography*, also influences climate. Mountains influence the temperature and moisture content of air masses. Ascending air or descending air on mountain slopes causes differences in temperature and precipitation on the windward and leeward sides of the mountain. Since temperatures usually decrease with altitude, higher elevation climates are usually cooler that sea level climates.

Proximity to Water Water heats up and cools down more slowly than land. Thus, large bodies of water affect the climates of coastal areas. Many coastal regions are warmer in the winter and cooler in the summer than inland areas of similar latitude.

It is not essential for students to know the details for classification each particular climate region based on latitude or on the Koppen classification system based on distribution of vegetation.

Assessment Guidelines:
The objective of this indicator is to *attribute* global climate patterns to geographic influences, therefore, the primary focus of assessment should be to determine from presented material the geographic influence that relates to the particular climate pattern. However, appropriate assessments should also require students to *summarize* the major points about how each factor influences climate; *compare* the climate in a coastal region with one inland or a climate on the windward side of a mountain with one on the leeward side of the mountain; or *recall* the main factors used to identify a climate.

ES-4.5 Explain the relationship between the rotation of Earth and the pattern of wind belts.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to global wind belts in 6th grade (6-4.9) as they studied the effects that global winds had on weather and climate conditions. The Coriolis effect has not been introduced in any prior grades.

It is essential for students to know that the circulation of the atmosphere is affected by the rotation of Earth on its axis. The rotation causes the surface winds in the Northern Hemisphere to be deflected to the right and those in the Southern Hemisphere to be deflected to the left. This motion is called the *Coriolis effect*. The Coriolis effect deflects winds that would otherwise blow directly from a high-pressure area toward a lower-pressure area from that path.

Because convection cells are in place in the atmosphere and Earth is spinning on its axis, *global winds* are found in each convection region. Students need to understand the *global wind belt* regions, the prevailing direction of the wind, and how air movement in these large regions affects weather patterns.

Trade winds:	• The *trade winds* blow from east to west in the tropical region moving warm tropical air in that climate zone. Like all winds they are names according to the direction from which they flow, the northeast trade winds or the southeast trade winds.
Westerly winds:	• The prevailing *westerly winds* blow from west to east in the temperate region. The temperate zone temperatures are affected most by the changing seasons, but since the westerly wind belt is in that region, the weather systems during any season move generally from west to east. Since the United States is in the westerly wind belt, the weather systems move across this country from west to east. (Tropical weather systems, for example, hurricanes, are moved in the prevailing easterly direction of the trade winds. If they enter the westerly wind belt, they are often turned, and move in the direction of that prevailing system.)
Polar winds:	• The *polar winds* blow northeast to west in the polar region, often called the polar easterlies, moving cold polar air in that climate zone from the poles toward the west. Where the polar easterlies meet warm air from the westerlies, a stormy region known as a *polar front* forms.

It is not essential for students to know the details of shifts in wind belts due to changes in seasons or the cause and effects of the jet streams.

Assessment Guidelines:
The objective of this indicator is to *explain* how the rotation of Earth is related to global wind belt patterns; therefore, the primary focus of assessment should be to construct cause and effect models of global winds responding to the Coriolis effect due to the rotation of Earth. However, appropriate assessments should also require students to *compare* the wind belt regions as to wind direction and influence on weather patterns; *recall* the effect on surface winds of the Coriolis effect; or *identify* global wind belts based on descriptions.

ES-4.6 Summarize the possible causes of and evidence for past and present global climate changes.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that some years Earth may be warmer, cooler, wetter, or drier than others, but on the average during a person's lifetime, climate does not change significantly. However, in Earth history evidence shows that Earth's climate has changed and is in a constant state of change. Major climate changes take long time periods.

Ice ages A long period of climatic cooling during which continental ice sheets, glaciers, cover large areas of Earth's surface is known as an ice age, or *glacial period*. Scientists have discovered several major glacial periods during Earth history. Features such as U-shaped valleys and moraine deposits are evidence of how far ice sheets advanced during an ice age.

Interglacial Period Times of warmer temperatures between the colder glacial periods are known as interglacial periods. Earth is currently experiencing such an interval.

Cause: One theory states that possibly a small change in Earth's orbit or in the tilt of Earth's axis occurs – basically a change in the amount of solar energy reaching Earth's surface. Another theory proposes that ice ages were caused by tectonic plate motion changing the position of the continents; others propose that volcanic dust blocked the Sun's rays.

Evidence: Evidence gathered from tree rings, ice-core samples, fossils, and radiocarbon sample provide evident of past climatic changes. Evidence has also come from the ocean floor in the shells of dead marine animals.

Present short-term climate changes also occur.

El Nino El Nino is a warm ocean current that occasionally develops off the western coast of South America forming around Christmas time about every three to ten years and lasting about a year. It can cause climate changes world-wide, especially in the tropics by weakening the trade winds in that area of the Pacific. This allows warm water to flow eastward instead of its usual westerly direction, changing the cool, dry region to a warmer, wetter one. It also changes the subtropical jet stream causing unusual weather around the world.

It is not essential for students to know the details of glaciers and ice movement.

Assessment Guidelines:
The objective of this indicator is to *summarize* the cause and evidence for past and present climate changes; therefore, the primary focus of assessment should be to generalize major points about these changes. However, appropriate assessments should also require students to *recall* conditions on Earth during an ice age; or *exemplify* (give examples of) evidence for climate change such as ice ages.

ES-4.7 Summarize the evidence for the likely impact of human activities on the atmosphere (including ozone holes, greenhouse gases, acid rain, and photochemical smog).
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that human activities have an impact on Earth's atmosphere. Global atmospheric effects include ozone depletion, global warming, acid precipitation, and air pollution, such as photochemical smog, ozone, and particulate matter.

Ozone depletion

Ozone depletion results from human activity through the use of chlorofluorocarbons (CFCs). CFCs are stable and harmless near Earth's surface but when they move into the upper atmosphere, they destroy ozone molecules that protect Earth from harmful ultraviolet radiation. Since the mid-1980s studies of the atmosphere have detected a thinning of Earth's protective ozone layer, most dramatically over Antarctica, called the "ozone hole". Because all CFCs released into the atmosphere are from man-made products, ozone depletion is entirely the result of human activity.

Global warming

It is natural for Earth's atmosphere to trap heat in the troposphere; this is known as the *greenhouse effect*. Global warming is the increase in Earth's average surface temperature. This is partly caused by human activities especially the burning of fossil fuels that significantly increases amounts of carbon dioxide, a main *greenhouse gas*, into the atmosphere. Carbon dioxide absorbs heat very readily. Increases in amount of carbon dioxide will intensify the greenhouse effect and may cause Earth to become warmer. Increases in global temperatures can have dramatic effects, such as changes in agricultural belts, glacier-ice cap melting resulting in rise in sea level, and difficulty of certain plants and animals to adapt resulting in extinction.

Acid precipitation

Acid precipitation, or *acid rain*, is defined as precipitation with a pH of less than 5.0. Natural precipitation has a pH of about 5.0 to 5.6, which is slightly acidic. Sulfuric and nitric acid results when precipitation combines with sulfur dioxide and nitrogen oxides in the atmosphere as a result of emissions from coal-burning power plants for example. These acids can be carried by winds long distances, thereby affecting areas far from their source. When acid precipitation makes its way into water bodies, it causes damage to the aquatic ecosystems and vegetation. It can affect plants and soil. Acid rain also damages stone buildings, statues, and even metal structures accelerating the processes of weathering and corrosion.

Air pollution

The air near Earth's surface can become polluted several ways. (1) *Photochemical smog*, a yellow-brown haze in the air, is caused by the action of solar radiation on an atmosphere polluted with hydrocarbons and nitrogen oxides, mostly from automobile exhaust systems. The air becomes harmful to breathe. (2) A major chemical in smog is ozone – in the upper atmosphere it is beneficial, but near the surface it is a pollutant. Ozone irritates the eyes, nose, and lungs of humans and is also harmful to plants. (3) Air pollution also occurs when particulate matter, such as carbon ash, dust, pollen, or asbestos fibers accumulate in the atmosphere. These particles are breathed in and lodge in the nose and lungs disrupting normal functions.

It is not essential for students to know the chemistry behind the formation of these types of pollution. They do not need to complete acid/base/neutralization reactions; although taking pH readings from water or soil samples might help in the summary. Even though this human impact leads to the need for reducing air pollution, that would be an interesting discussion but not essential to this indicator.

Assessment Guidelines:

The objective of this indicator is to *summarize* the evidence for human impact on the atmosphere; therefore, the primary focus of assessment should be to generalize major points about the ways that human activity has resulted in changes in Earth's atmosphere. However, appropriate assessments should also require students to *compare* these various types of atmospheric effects; *compare* the types and sources of air pollution; *identify* the causes of these impacts on the atmosphere; or *recall* the effects that these impacts can have on human beings and the environment.

ES-4.8 Predict weather conditions and storms (including thunderstorms, hurricanes, and tornadoes) on the basis of the relationship among the movement of air masses, high and low pressure systems, and frontal boundaries.
Taxonomy level: 2.5-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 4th grade summarized the conditions and effects of severe weather including thunderstorms, hurricanes, and tornadoes. In 6th grade students summarized the relationship of the movement of air masses, high and low pressure systems, and frontal boundaries to storms and other weather conditions. In Earth Science this foundation will be deepened as the complexity of air movement of and within weather systems are studied so that predictions can be made.

It is essential for students to know that air masses, high and low pressure systems, and frontal boundaries are the major causes of weather variations and storms. Many meteorological processes involve atmospheric movement, such as convection, on different scales. *Weather* is the current, day-to-day, conditions of the atmosphere. Predicting weather conditions and storms comes from knowing that they are part of and the result of relationships among the following factors in the atmosphere.

Air masses Students need to know how an air mass forms, the types of air masses that usually affect North America, and the source regions for these air masses. They should understand that as air masses move their characteristics modify according to the surface(s) over which they travel.

High pressure system Students need to know that sinking air is associated with high pressure systems, also called *anticyclones*. With the Coriolis effect, sinking air circulates downward and to the right in the northern hemisphere spreading away from the center when it reaches Earth's surface. High pressure systems rotate clockwise. High pressure systems are usually associated with fair weather and generally pleasant conditions.

Low pressure system Students need to know that in surface low pressure systems, also called *cyclones*, air rises. Rising air must be replaced, so the flow of air is inward toward the center and then upward. A low pressure system in the northern hemisphere moves in a counterclockwise direction. Low pressure systems are usually associated with clouds and precipitation.

Fronts Students need to know how air masses influence the formation of the four main types of fronts: *cold* front, *warm* front, *occluded* front, and *stationary* front. They need to know the direction of airflow within the frontal region and what factor(s) influences the direction of frontal movement. They need to know the characteristic cloud formations and weather patterns that result from each frontal boundary.

The information about the factors that influence weather conditions is also important for students to understanding storms. The major storms – thunderstorm, hurricanes, and tornadoes, are associated with low pressure cyclonic movement of air and/or frontal boundaries. Students need to know the conditions under which these storms form, how they are related to the factors that influence weather conditions (air masses, pressure systems, and fronts), and also factors concerning their duration and severity. Plotting the course of a hurricane and predicting it possible path based on atmospheric conditions is also essential in the study of this storm.

It is essential for students to use weather map data that includes air masses, pressure systems and isobar lines, and fronts (as well as station model data) to predict weather conditions in regions across the United States.

It is not essential for students to actually collect weather data using weather instruments (4th and 5th grade). The reading of radar images or infrared satellite images though interesting is not essential.

Assessment Guidelines:
The objective of this indicator is to *predict* weather conditions and storms; therefore, the primary focus of assessment should be to make logical predictions from presented information, including air masses, high and low pressure systems, and frontal boundaries. However, appropriate assessments should also require students to *summarize* the formation and severity of different storms; *compare* high and low pressure systems; *compare* the formation and weather conditions of the different fronts; *interpret* diagrams or illustrations of air masses, pressure systems, or fronts; or *predict* weather conditions from information on a weather map.

Topic: Earth's Hydrosphere

ES-5 The student will demonstrate an understanding of Earth's freshwater and ocean systems.

Key Concepts:
Surface water: water cycle; lakes, rivers and drainage basins, wetlands
River systems: stages in river development – youthful, mature, old, rejuvenated
Groundwater: karst topography, chemical weathering, sinkholes and caverns
Seawater/Freshwater: physical properties, chemical properties
Shoreline interactions: waves, currents; shoreline features
Shoreline control: jetties, breakwaters, groins; sand dune vegetation anchoring
Transfer of energy: surface currents, deep currents; photosynthesis, chemosynthesis
Water pollution: point and nonpoint sources; groundwater pollution, ocean pollution

ES-5.1 Summarize the location, movement, and energy transfers involved in the movement of water on Earth's surface (including lakes, surface-water drainage basins [watersheds], freshwater wetlands, and groundwater zones).
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 6th grade summarized the dynamics of the water cycle including surface-water flow and groundwater flow. In 7th grade students studied the location and movement of water on Earth's surface in groundwater zones as well as surface-water drainage basins making them important to ecosystems and human activities. In Earth Science these concepts will be further studied as energy transfer is attributed to this continual movement of water on Earth.

It is essential for students to know that Earth's water supply is continually being recycled across Earth's surface in a process known as the *water cycle*. The mechanics of the water cycle helps to explain the variations in the amount of water available throughout the world. Energy from the Sun is the driving force of this cycle. As water returns to Earth as precipitation, it may flow down slope along Earth's surface as runoff. Runoff may reach a stream, river, lake or wetlands area in its eventual surface flow toward the ocean.

Lakes	Students should understand the conditions for a lake to form, how a lake is continually supplied with water, and movement of water within the lake.
Streams & Rivers	Students should understand how stream systems form as water flows and collects in surface channels. Tributaries forms as streams flow into each other. A large stream is called a river, and all tributaries make up a river system. They should know the factors that affect the speed of water flow and also what would cause rejuvenation of river flow.
Drainage Basin	Students should be able to locate and trace the movement of water in a drainage basin, also called a *watershed*, by determining the land area that drains into a particular stream or river system. A *divide* is the high land area that separates one watershed from another.
Freshwater Wetlands	Students should know that a wetland area is land that is covered with water for a large part of the year. They should know the various types of wetlands, the supply of water for wetlands, and the reason(s) for change in amount of water within a wetland area.

Students should also know that water that seeps into Earth's surface becomes *groundwater*. They should understand the conditions on the surface that would allow water to move downward into the ground, such as vegetation, rate of precipitation, rock or soil composition, as well as slope of the land area. Once water moves into the ground, zones of groundwater form. Students should understand the relationship of groundwater to the *zone of saturation, the water table, and the zone of aeration*. Students should also understand the formation of stored underground water in an *aquifer*.

It is not essential for students to know uses of surface water or groundwater as it moves through Earth's surface. They do not need to know the names for the surface water patterns or the reasons for changes in stream/river flow patterns.

Assessment Guidelines:
The objective of this indicator is to *summarize* information about water flow on and within Earth's surface; therefore, the primary focus of assessment should be to generalize major points the location, the movement, and the energy that drives water to cycle on Earth's surface. However, appropriate assessments should also require students to *explain* how the Sun affects the location and movement of water on Earth's surface; *compare* the movement of water in a lake with that in a river or *compare* a lake to a wetlands area; *illustrate* by using maps the location of a drainage basin and divide; or *recall* groundwater zones.

ES-5.2 Illustrate the characteristics of the succession of river systems.
Taxonomy level: 2.2-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 7th grade were introduced to river systems as they studied drainage basins and divides. Students have not been introduced to the concept in this indicator in any previous grade.

It is essential for students to know some of the physical features of the stages of development as a river system forms.

Youthful/Young Rivers:
The condition of the headwater where water first accumulates to form the young river is important as well as stream channel characteristics. The formation of river valleys, along with waterfalls and rapids, also show a youthful river system. The fast-moving water erodes away rock and soil as it moves over steep inclines.

Mature Rivers: Well-established tributaries and good drainage in the watershed are characteristics of mature rivers. They carry a larger volume of water and form a broader floodplain. The gradient is less steep than a youthful river. A mature river may *meander* across its channel area. Erosion and deposition take place along the river bends. A meander may even be isolated by deposits and form an *oxbow lake*.

Old Rivers: With an even lower gradient, the old river moves slowly. The river channel becomes deeper. It no longer erodes the land. Few tributaries enter as most have already merged into the mature river. A broad flat floodplain is formed. As a river loses velocity when entering a large body of quiet water, the sediment load drops forming a triangular deposit called a *delta.*

Rejuvenation: When the land over which a river is flowing uplifts or if the base level lowers, the stream takes on the features of a young river again; it rejuvenates. Depending upon the rate of water flow, erosion again takes place cutting the river channel.

It is not essential for students to know the types of stream load or how terraces form along rejuvenated rivers. Methods of controlling water along and within river systems and floodplains is also not essential but may offer interesting discussion as to their use as safety measures and their effectiveness.

Assessment Guidelines:
The objective of this indicator is to *illustrate* characteristics of river system succession; therefore, the primary focus of assessment should be to give or use illustrations such as diagrams, pictures, or word descriptions to show different stages of a river system. However, appropriate assessments should also require students to *compare* the stages of river succession; or *identify* characteristics of a stage in river succession.

ES-5.3 Explain how karst topography develops as a result of groundwater processes.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concept in this indicator in any previous grade.

It is essential for students to know that water is a powerful agent of erosion at work underground as well as on Earth's surface. Groundwater that passes through *permeable* rock dissolves minerals in the rock. Water that moves through organic materials and soil may become acidic, chemically weathering the rock as it passes through. Rocks that contain calcite, such as limestone, are susceptible to chemical weathering.

Students should know that regions where the chemical weathering effects are visible are said to have *karst topography*. These features include sinkholes, caverns, and streams that disappear into cracks in the rock emerging in caves or out cracks long distances away.

Students should understand how sinkholes and caverns form. The formation of cavern characteristics such as stalactites and stalagmites is also essential.

It is not essential for students to know the chemistry of the processes that take place when rock undergoes chemical weathering. The study of wells, springs, hot springs, and geysers is not part of karst topography.

Assessment Guidelines:
The objective of this indicator is to *explain* how karst topography results from groundwater processes; therefore, the primary focus of assessment should be to construct cause and effect models of groundwater chemical weathering resulting in karst topography formations. However, appropriate assessments should also require students to *summarize* the formation of stalactites and stalagmites; *exemplify* types of karst topography; or *identify* karst topography features from descriptions, pictures, or diagrams.

ES-5.4 Compare the physical and chemical properties of seawater and freshwater.
Taxonomy level: 2.6-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 3rd grade located saltwater and freshwater features on Earth. In 5th grade they studied mixtures and solutions, properties of water as a solvent. In Earth Science the study deepens as students have the basic chemistry background to understand in greater detail the properties of these two types of water found on Earth.

It is essential for students to know that freshwater and seawater have unique properties that are important to processes on Earth. Pure water is a chemical compound whose molecule consists of hydrogen and oxygen (formula = H_2O). Water is not chemically reactive. As the universal solvent, water can dissolve many materials into solution.

Freshwater Freshwater is one of Earth's more abundant and important renewable resources. It can be found within the temperature conditions on Earth in all three states of matter. As a liquid, it flows over Earth's surface and into the ground. It takes the shape of various containers on Earth – lakes, ponds, aquifers, and rivers. As a solid freshwater is found in glaciers, snowfields, and the ice caps of Earth. Water vapor in the atmosphere is the great mover of water from one location to another on Earth. Freshwater is a mixture that contains more substances than just pure water. As water dissolves materials in rock and soil or pollutants in the air, it can form acid solutions that change the atmosphere, precipitation, and land formations of Earth. Freshwater has a density of about 1.0 g/cm^3 and freezes at 0°C.

Seawater Seawater is also a mixture, but it contains more dissolved substances than freshwater. It is a solution of about 96.5% water and 3.5% dissolved salts. The most abundant salt in seawater is sodium chloride (NaCl). Other chloride and sulfate salt compounds are also present. Dissolved gases, such as oxygen, nitrogen, and carbon dioxide, are also present along with dissolved nutrients. The salinity of ocean water varies from place to place. High salinities are found in areas where evaporation is high or seawater is freezing; low salinities occur where freshwater empties into oceans. Other physical properties of seawater include a density of about 1.02 – 1.03 g/cm^3. The freezing point of seawater is lower than freshwater at -2°C.

Students should know that both freshwater and seawater respond to solar radiation that strikes the Earth's water surfaces.

Visible Light: Water both absorbs and reflects light. Most sunlight that reaches Earth falls on the oceans; this sunlight penetrates the surface and is absorbed by water. Most wavelengths of *visible light* are absorbed, but blue light tends to be reflected. All wavelengths of light are absorbed by about 100m depth, so deep lakes and the oceans are dark except for surface region.

Infrared Rays: Water also has the ability to absorb infrared wavelengths of sunlight. Infrared rays play an important role in determining the temperature of water. Rapidly moving water in fast-moving streams and rivers does not have time to absorb infrared waves. Lakes and ponds, especially shallow ones, become warm as the infrared rays are absorbed. Infrared rays are completely absorbed within the upper zone of ocean water; thus it heats the water only near the surface of the ocean. Surface temperature does vary with latitude – polar seawater is cold or even frozen depending upon the season. Tropical seawater is generally warm all year. Seawater deep in the ocean is very cold.

It is not essential for students to know the atomic structure of a water molecule or how its chemical shape makes it a polar molecule.

Assessment Guidelines:
The objective of this indicator is to *compare* properties of freshwater and seawater, therefore, the primary focus of assessment should be to detect ways that freshwater and seawater are alike or different in regards to their properties. However, appropriate assessments should also require students to *summarize* major points about the properties of freshwater or seawater; *interpret* charts or graphs of light or temperature differences with water depth; or *recall* the reason water in lakes or the ocean appears blue in color rather than clear.

ES-5.5 Explain the results of the interaction of the shore with waves and currents.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to features along the shore zone in 5th grade. 5th grade students also studied the affect that waves, currents, tides, and storms have on the geologic features of the ocean shore zone. They compared the movement of water by waves, currents, and tides. In Earth Science the students will explain these actions with greater understanding of the characteristics and motions of waves and currents causing changes along the shore.

It is essential for students to know the characteristic motion of *water waves*, including the factors that affect the height of a wave. They should know the cause of breaking waves and their effects on the shoreline. *Surface ocean currents* usually only affect the temperature of the shore area waters. *Longshore currents* transport sediment. Since most beaches consist of loose sediments, longshore currents can spread them out in the direction of the current flow along the shore. Large waves are associated with fast moving longshore currents and lots of sediment transport.

Students should have an understanding of *longshore current transport*. As a result of wave erosion, longshore current transport, and sediment deposition, the shoreline is in a constant state of change. Sediments eroded in one area are moved and deposited in another building various coastal landforms, such as sandbars, spits and barrier islands. Students should know how these features form and change due to wave action and current transport.

It is not essential for students to know about the cause and effects of tides on the shore zone. They do not need to study density ocean currents, turbidity currents, or upwellings with this indicator.

Assessment Guidelines:
The objective of this indicator is to *explain* the results of interactions of the shore with waves and currents; therefore, the primary focus of assessment should be to construct cause and effect models of how waves and currents cause changes along the shoreline. However, appropriate assessments should also require students to *compare* the effects of strong wave action with gentler wave action; *summarize* the action of longshore current transport; or *identify* shoreline features caused by wave action or longshore transport.

ES-5.6 Summarize the advantages and disadvantages of devices used to control and prevent coastal erosion and flooding.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that in coastal areas structures such as seawalls, groins, jetties, and breakwaters are built in an attempt to prevent beach erosion and destruction of oceanfront properties.

Students need to study each of these structures to determine the advantage each gives to control and prevent coastal erosion and flooding. Where structures are not built, beach nourishment, which involves adding large quantities of sand to the beach system, is sometimes used.

Along with advantages, students need to study the disadvantages of these structures as they are built along the coastlines, as well as problems with beach nourishment.

An overall understanding that students need to have in regards to this concept is that the shoreline is not stable; shorelines continually undergo change. Erosion and deposition are natural processes of the interaction of ocean water with coastal features.

It is not essential for students to evaluate or judge the value of devices built along the coastal areas.

Assessment Guidelines:
The objective of this indicator is to *summarize* advantages and disadvantages of devices built along coastal areas; therefore, the primary focus of assessment should be to generalize major points about why these devices are needed to control and prevent erosion and flooding and why they are drawbacks to the natural change of the coastline. However, appropriate assessments should also require students to *explain* the effect a structure would have if built along the coastline; *identify* the reason for structures to be built along the coastline; or *exemplify* (give examples of) structures built along coastal areas.

ES-5.7 Explain the effects of the transfer of solar energy and geothermal energy on the oceans of Earth (including the circulation of ocean currents and chemosynthesis).
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concepts in this indicator in any previous grade.

It is essential for students to know that solar energy penetrating the surface water region of the ocean and geothermal energy from thermal vents deep within the ocean have affects on the movement and chemical reactions that take place in ocean waters.

Ocean currents

Surface currents: As solar energy reaches Earth's oceans most directly in areas near the equator, surface water in that region is warmer. The surface ocean water is set into motion by energy from the wind. The wind belts determine the direction of the flow, but the Coriolis effect and interaction with continents also help determine surface ocean current direction of movement. Warm equatorial surface currents flow and bring warm water to cooler regions. Currents coming from areas near the poles where solar energy is less direct are cold currents. As cold currents move toward the equator, they cool the region around them.

Deep currents: Water warmed by solar energy near the equator expands and is less dense that cold water. Cold water from the poles is more dense, sinks, and moves very slowly beneath warmer ocean water toward the equator.

Chemosynthesis Some regions of the ocean are teeming with life due to organisms using solar energy for photosynthesis. The most abundant marine life exists where there are ample nutrients and good sunlight. In deep ocean areas where sunlight does not reach, chemosynthesis (chemical reactions) supports life near hydrothermal vents, mainly along the oceanic ridge. Microscopic bacteria living in and near the vents perform chemosynthesis and become the bottom of the food web. Through chemosynthesis, the bacteria produce sugars and other foods that enable them and many other organisms to live in this very dark, very unusual environment.

It is not essential for students to know the names of specific warm or cold ocean currents – the explanation here is about solar energy affecting the currents. Students are not responsible for knowing the classification of marine life or the various marine life zones.

Assessment Guidelines:
The objective of this indicator is to *explain* how solar energy and chemosynthesis affect Earth's oceans; therefore, the primary focus of assessment should be to construct cause and effect models of how solar energy affects ocean current movement and life in the ocean, and also how chemosynthesis affects life where solar energy does not reach. However, appropriate assessments should also require students to *compare* surface ocean currents with deep ocean currents; *compare* marine life where solar energy reaches with marine life where it is dark; *recall* the process of chemosynthesis; or *identify* the reason that warm ocean currents exist.

ES-5.8 Analyze environments to determine possible sources of water pollution (including industrial waste, agriculture, domestic waste, and transportation devices).
Taxonomy level: 4.-B Analyze Conceptual Knowledge

Previous/future knowledge: Students in 5th grade explained how mixing and dissolving of foreign materials is related to water pollution. In 7th grade students explained the implications of depleting and the importance of conserving resources, such as water. In Earth Science this foundation will be deepened as specific sources of water pollution in the environment are analyzed.

It is essential for students to know that water is an essential resource on Earth. Organisms on Earth depend on water for life. Humans depend on water in many ways. Water pollution is an area where humans have an impact on water supplies.
Surface water pollution can be grouped into two main types: point sources and nonpoint sources.

Point sources Students need to know that point source pollution is generated from a single point of origin. When analyzing an environment for water pollution sources, students may find the source to be a sewage treatment plant for domestic waste, or an industrial site. Improper bacteria and viruses that result from disposal of sewage, or toxic wastes that enter streams can send this pollution downstream into the environments.

Nonpoint sources Students need to know that nonpoint sources of pollution generate pollution from widely spread areas. Rainwater absorbs air pollutants and may become acidic, bringing down precipitation far from its origin. Rainwater may also drain fertilizers and pesticides from agricultural sites, or wash oil, gasoline, and other chemicals from roads and parking lots. Nonpoint sources are not as easily identified nor as easily cleaned up as point sources.

Not only is surface runoff water a carrier of pollutants, pollution can find its way into groundwater and into the ocean.

Groundwater pollution Students need to know that some water filled with chemicals, road salt, fertilizer, sewage or other pollutants may find its way into groundwater and aquifers in a region. Once groundwater is contaminated, the pollutants can be very difficult to remove.

Ocean pollution Students need to know that pollution of ocean water is also a concern. Near-shore regions and estuaries are often the first regions of the ocean to become polluted. Sewage water is the most common source.

In analyzing the sources of water pollution, students need to realize the importance of clean-up efforts and the importance of reducing water pollution. When there is not enough water to go around, water conservation is most important.

It is not essential for students to actually collect water pollution samples for analysis.

Assessment Guidelines:
The objective of this indicator is to *analyze* environments for sources of water pollution; therefore, the primary focus of assessment should be to carefully study environments to determine how the information could identify pollution sources. However, appropriate assessments should also require students to *exemplify* (give examples of) the various sources of water pollution; *compare* point and nonpoint pollution; or *infer* a pollution source from its description.

Topic: The Paleobiosphere

ES-6 The student will demonstrate an understanding of the dynamic relationship between Earth's conditions over geologic time and the diversity of its organisms.

Key Concepts:
Planet conditions: hydrosphere, atmosphere, biosphere
Geologic time: geologic time scale – eons, eras, periods, epochs; complexity & diversity of life
Fossil evidence: types of fossils within various environments
Geologic dating methods: index fossils, relative dating, radiometric dating
Age of universe & Earth: cosmology

ES-6.1 Summarize the conditions of Earth that enable the planet to support life.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students have studied throughout elementary grades the needs that plants and animals must have in order to survive and reproduce. In 6th grade students summarized characteristics that all organisms share, such as the obtainment and use of resources for energy, that they would get from the environment. In 7th grade students studied the biotic and abiotic environment of Earth and how organisms interacted and responded to the components of the environment. In Earth Science students will focus on Earth as the unique planet with the conditions that can support life.

It is essential for students to know that without Earth's hydrosphere, atmosphere, and environments of the biosphere, life could not exist on Earth.

- Earth is suitable for life because of its unique orbital position that allows for water to exist in all three phases on the surface. Water makes Earth unique. The *hydrosphere*, Earth's mass of liquid water that is constantly on the move, is vital to life within it and also to life on the land.
- Earth is surrounded by a life-giving gaseous envelope called the *atmosphere*. Earth's atmosphere provides the air that organisms need to breathe and also acts to protect organisms from the Sun's intense heat and radiation.
- The *biosphere* includes all life on Earth – life found from the depths of the ocean floor to life existing in the lower atmosphere. This biosphere contains the biotic and abiotic environments necessary for organisms to breathe, obtain/make food, find shelter, and reproduce. Organisms not only respond to the environmental conditions on Earth, but through interactions, they help maintain and alter the environment also.

Students should know that scientists examine evidence from the rock record and fossils to develop their theories about life and the changes in Earth's conditions for its existence. During the formation of these spheres of Earth, scientists have found evidence that life forms went through many changes in order to exist. Geologic changes, changes in the amount of Earth's surface water, changes in the atmosphere resulting in climatic changes and temperature changes have affected the life forms in existence through the history of Earth.

It is not essential for students to know evolutionary theory with this indicator; students are focusing on Earth conditions for survival, not natural selection and organism change over time.

Assessment Guidelines:
The objective of this indicator is to *summarize* the conditions on Earth that are necessary for the support of life; therefore, the primary focus of assessment should be to generalize major points about how Earth as a planet meets of the needs of living things. However, appropriate assessments should also require students to *infer* how the hydrosphere or atmosphere or biosphere gives Earth life-sustaining properties; or *identify* the spheres of Earth necessary for life on the planet.

ES-6.2 Recall the divisions of the geologic time scale and illustrate the changes (in complexity and/or diversity) of organisms that have existed across these time units.
Taxonomy level: 1.2-A Remember Factual Knowledge
2.2-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to the geologic time scale and the vast diversity of life that it presents in 8th grade. Earth Science will further develop this concept.

It is essential for students to know that scientists have developed a geologic history of Earth from evidence found in the rock layers. The type of rock that makes up the layer and the fossils that are found in each layer help to reveal information about the conditions that existed when the layer formed. Fossils also indicate the kinds of organisms that lived during that geologic time.

Students need to know the major divisions, *eons* and *eras*, and the fact that *periods* within the eras were further divided based on the life-forms that were abundant or became extinct during the time those rocks were deposited. A further division during the Cenozoic Era is *epochs*. Since the rock record during this last era is relatively complete with less time for change due to weathering and erosion, different groups of organisms can be used to distinguish the various epochs.

Students should study various illustrations of the geologic time scale noting major geologic events taking place on Earth. They should use the information on the illustrations to note changes in life forms both in the complexity of the organisms (e.g. simple marine invertebrates to plant life to vertebrate amphibians and reptiles to flowering plants to mammals) and the diversity of those life-forms through time.

It is not essential for students to memorize the names of the periods and epochs on the geologic time scale – the order of the major eras is important. Students should not have to identify life forms in existence during various periods or epochs unless a geologic time scale illustration is available for interpretation.

Assessment Guidelines:
The objective of this indicator is first to *recall* the divisions of the geologic time scale; therefore, the primary focus of assessment should be to retrieve relevant knowledge about this scale from long-term memory; another objective of this indicator is to *illustrate* the changes in life forms on Earth over geologic time; therefore, the primary focus of assessment should be to find or use illustrations of the geologic time scale to show how life forms have changed in complexity and diversity over time. However, appropriate assessments should also require students to *classify by sequencing* the order of the eras on the geologic time scale; or *summarize* major changes that occurred in life forms over geologic time.

ES-6.3 Summarize how fossil evidence reflects the changes in environmental conditions on Earth over time.
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/future knowledge: Students were introduced to fossils, and some of the types of fossils, in 3rd grade; they also studied how fossils could give scientists ideas about early environments. In 8th grade students summarized how scientists used many types of fossils to study Earth's diverse life forms and changing environments. In Earth Science students will develop this concept further as they study evidence from fossil populations of organisms that indicate changes in their environment.

It is essential for students to know that there are various types of fossils. Some may be direct evidence of the organism such as shells, bones, or plant fragments; others may be indirect evidence, such as tracks, trails, or footprints. Students may review the various types of fossils from their previous learning.

Students should also know that a fossil is considered to be originally preserved when the organism remains as it was when it died; it is considered to be an altered fossil when all of the organic material has decomposed and been replaced by minerals deposits.

Fossils of all types furnish scientists with clues to changes that have occurred in Earth's past history, such as changes in climate and environment. If a fossil of a warm climate reptile is found in a northern colder region today, the fossil indicates that that area once had a tropical climate. Tropical plants have been found in Antarctica; fossils of marine animals have been found far from any ocean. Students should be researching examples of fossil organisms that give scientists these clues.

The study of fossils allows scientists to

- describe how organisms have changed through time;
- have evidence of ancient environmental conditions;
- find patterns and cycles that can be used to predict future phenomena, such as climactic changes;
- locate energy resources based on the environmental conditions needed for fossil fuels to have formed.

It is not essential for students to know how each fossil type was formed, unless this is in context of review. This indicator is not a complete study of the environmental conditions on Earth over time.

Assessment Guidelines:
The objective of this indicator is to *summarize* how fossil evidence reflects changes in environmental conditions on Earth; therefore, the primary focus of assessment should be to generalize major points what fossils can reveal about these changes. However, appropriate assessments should also require students to *recall* different types of fossils; *exemplify (give examples of)* fossils that could be found in various environments; or *infer* a type of environment based on fossil evidence.

ES-6.4 Match dating methods (including index fossils, ordering of rock layers, and radiometric dating) with the most appropriate application for estimating geologic time.
Taxonomy level: 2.6-B Understand Conceptual Knowledge

Previous/future knowledge: Students in 8th grade were introduced to index fossils and to determining the relative age of rocks through the ordering of rock layers. Students have not studied radiometric dating before this indicator in Earth Science.

It is essential for students to know that rocks contain clues to Earth's past, including life forms and evidence of geologic change. Several ways to learn about and date Earth's past come from the type of rock found, the rock layers, and fossils found within some of the rocks. Methods of dating the Earth are determined by whether the need is for which came first and sequencing to later dates, or whether the need is for an actual age.

Relative Age Dating: (used if the need is for ordering oldest to youngest in geologic time)
Ordering Rock Layers

Students should know how the geologic principles of *uniformitarianism*, *superposition*, and *cross-cutting relationships* help to determine the ordering of rock layers and changes that occur to those rock layers over time. They should know how weathering and erosion disturb the rock layering, and how an intrusion or a fault can indicate younger or more recent changes to the rock layer(s) in which they are found.

Index Fossils: (used to aid in the ordering of rock layers or to age the rock layer)

Students should know that geologists use index fossils to correlate rock layers over large geographic areas and to date a particular rock layer. An *index fossil* must be easily recognized, have been abundant and widely distributed geographically. It also must have lived during a short period of time. With this information, a scientist can use index fossils to date the age of the rock layer based upon when that organism was known to have lived in geologic time. An index fossil found in rock layers in different areas of the world indicates that the rock layers were probably formed during the same period.

Radiometric/Absolute Age Dating: (used if the need is for knowing the actual age of a rock or fossil)

Students should know that in order for scientists to determine the actual age, or *absolute age*, of a rock layer, radioactive isotopes of elements found in rocks or fossils are used. *Radioactive isotopes* give off energy and particles at a regular rate, not influenced by environment, temperature, or any other changes, and eventually change to other isotopes of that element or into an isotope of a different element. They function as a natural clock. This process is called *radioactive decay*. By knowing how long a radioactive element takes to decay into its "daughter" elements, and by determining the ratio of the original radioactive element still present compared to the amount of "daughter" element, the age of the rock being analyzed can be determined. Since this process takes a long period of time for most radioactive elements, geologist use the length of time its takes for one-half of the original amount to decay, called the *half-life*, to determine age. Students should know why uranium-238 may be used for one dating compared to carbon-14 in another instance.

It is not essential for students to know the details of the particles given off or the various daughter elements that occur in the radioactive decay process; only a general understanding of radioactive decay is essential.

Assessment Guidelines:
The objective of this indicator is to *match* methods of dating rocks and fossils with appropriate need for the dating, therefore, the primary focus of assessment should be to determine from the need indicated whether relative dating, index fossils, or absolute/radiometric dating would be the best method to use. However, appropriate assessments should also require students to *summarize* the major points about each type of dating method; *compare* relative and absolute dating; *infer* the age of a rock through the use of half-life; or *recall* the geologic principles involved in relative dating.

ES-6.5 Infer explanations concerning the age of the universe and the age of Earth on the basis of scientific evidence.
Taxonomy level: 2.5-B Understand Conceptual Knowledge

Previous/future knowledge: Students have not been introduced to the concept in this indicator in any previous grade.

It is essential for students to know that scientists collect data using various types of telescopes and instruments to detect changes that are going on out in the universe. This study, called *cosmology*, not only studies the universe as it is, but also forms models and theories concerning it origin and age.

Students should study the scientific evidence and use that evidence to make inferred explanations about the age of the universe.

Students should also know that scientists are collecting and analyzing data used to develop theories about the age of Earth. Radiometric dating has determined the age of the oldest rocks on Earth at present time but the rocks that form Earth's crust have been eroded over time. Meteorites and moon rocks have also been studied for evidence of age.

Students should study the scientific evidence and use that evidence to make inferred explanations about the age of Earth.

It is not essential for students to know the details and mathematics (e.g. use of the Hubble constant) of all the scientific evidence; but a general understanding of what scientists have discovered, used, and analyzed in order to come up with a determination of the age of the universe and Earth is appropriate.

Assessment Guidelines:
The objective of this indicator is to *infer* the age of the universe and Earth; therefore, the primary focus of assessment should be to draw scientifically based conclusions/explanations based on evidence gathered by scientists. However, appropriate assessments should also require students to *summarize* methods that scientists use to gather information from across the universe or from on Earth to determine age; *recall* the purpose of the field of science called cosmology; or *identify* the age of the universe and the Earth as determined by scientists.