Earth's Changing Surface - LPS Objectives and Textbook Chapters

6.1 Earth’s Changing Surface - By the end of 6th grade, students will investigate and understand facts, concepts, principles, and models that are related to the destructive forces affecting the Earth's surface.

6.1.1 Identify and describe the Earth's surface.
   a. Name and describe the main landforms and the Earth's four spheres. (Chapter 1, Section 1)

6.1.2 Identify and investigate weathering, erosion, and their effects.
   a. Identify and discuss causes of mechanical and chemical weathering and the factors that affect the speed of weathering. (Chapter 2, Section 1)
   b. Describe the composition of soil and explain how it formed. (Chapter 2, Section 2)
   c. Identify ways soil is lost or destroyed and explain the importance of soil conservation. (Chapter 2, Section 3)
   d. Name and describe processes that wear down the Earth's surface. (Chapter 3, Section 1)
   e. Explain gravity as a force that affects erosion. (Chapter 3, Section 1)
   f. Explain water erosion and describe features formed by it. (Chapter 3, Section 2)
   g. Describe land features formed by sediment. (Chapter 3, Section 2)
   h. Explain how sediment enters moving water and list factors that affect water's ability to erode and carry sediment. (Chapter 3, Section 3)
   i. Name and describe two types of glaciers and ways they erode land. (Chapter 3, Section 4)
   j. Explain how glaciers deposit sediments and the role of glaciers in the Earth's history. (Chapter 3, Section 4)
   k. Identify how ocean waves get their energy and explain how waves shape landforms and change coastlines. (Chapter 3, Section 5)
Earth's Changing Surface – Content Background

6.1.1 Identify and describe the Earth's surface.

a. Name and describe the main landforms and the Earth's four spheres. (Chapter 1, Section 1)

**Topography** - the shape of the land (top-=place, -graph=record)

**Topography** is determined by:

1. **Elevation** - height above sea level of a point on the Earth's surface
2. **Relief** - difference in elevation between highest and lowest parts of an area
3. **Landforms** - feature of topography formed by the processes that shape Earth's surface (have elevation and relief)

**Landform region** - large area of land with similar topography

Types of landform regions:

1. **Plains** - flat or gently rolling land with low relief
2. **Mountains** - high elevation and high relief
3. **Plateau** - high elevation and more or less level (flat) surface

Earth's four spheres:

1. **Lithosphere** - Earth's solid, rocky outer layer (litho-= stone)
2. **Atmosphere** - mixture of gasses that surrounds the Earth (atmo-=vapor)
3. **Hydrosphere** - oceans, lakes, rivers, and ice (hydr-= water)
4. **Biosphere** - all living things (bio-= life)

6.1.2 Identify and investigate weathering, erosion, and their effects.

a. Identify and discuss causes of mechanical and chemical weathering and the factors that affect speed of weathering. (Chapter 2, Section 1)

**Weathering** refers to the processes that break up and corrode solid rock at the surface of the Earth, eventually transforming it into sediment.

1. **Mechanical** or **physical weathering** is the type of weathering in which rock is physically broken into smaller pieces.

Five main processes cause mechanical weathering:

1. **Jointing** - Most rocks form well beneath the surface of the Earth, under conditions of higher temperature and pressure than at the surface. Once rock is uplifted to the surface, the decreased pressure and temperature can cause the rock to change shape, and usually causes cracks in rock called **joints**.
2. **Freezing and thawing** (expansion of compound within rock) - Because water expands when it freezes, liquid water that seeps into cracks and spaces between or within rocks tends to make those cracks or spaces bigger as it freezes. This process is particularly important in relatively wet areas with significant seasonal temperature changes; most mountainous regions experience a great deal of mechanical weathering by freezing and thawing. A demonstration of the power of expanding ice is described on pg. 45 of the textbook (“Science at Home”).

In dry areas, dissolved salt in groundwater can crystallize and grow in pore spaces in rock, causing the rock to crumble in much the same way as by the expansion of water to ice. This can also occur as a result of salt added to sidewalks and streets to prevent the formation of ice. This process is known as **salt wedging**. Because it acts to physically force rocks apart rather than through a chemical reaction, it is considered a type of mechanical weathering.

3. **Thermal expansion** - Like most materials (but not water), rock expands when heated and contracts when cooled. Extreme heating of rocks (like that which occurs in some forest fires) is enough to force the outer part of the rock to break off or **spall**.

4. **Plant growth** - Plant roots can cause an amazing amount of damage to sidewalks over just a few years – they can do the same thing to rock, and over a long time span, plant roots also can break the rock into smaller pieces.

5. **Animals** - Burrowing animals (like earthworms) can act to break rocks apart by digging through cracks and weak spots. Humans also create a large amount of mechanical weathering through mining, road building, and other construction.

Although the textbook refers to the process of **abrasion** as a kind of mechanical weathering, abrasion is much more important in **erosion** (processes loosening rock, separating it from its substrate, and carrying it away) and **transportation** (movement of sediment by wind, water, or ice some distance).

2. **Chemical weathering**, the breakup of rock through chemical changes, also occurs through a number of processes. The most important are **reactions of minerals within rock with water, oxygen, and acids, and through reactions mediated by living things**.

Unlike mechanical weathering, chemical weathering produces sediments that have a different mineral composition from the original or parent rock.

1. **Water** chemically reacts with rocks primarily by dissolving or reacting with the minerals to create new minerals. The dissolution of rock salt completely into water is a good example of the former process. Minerals in the rock granite are chemically altered by water, destroying some minerals and creating new ones.

2. **Oxygen** combines easily with many elements in chemical reactions. One example is the rusting of iron, a familiar reaction that works the same way with iron-bearing minerals in rocks.

3. **Acids** - Most water at the surface of the earth is slightly acidic, produced as rainwater dissolves carbon dioxide gas in the atmosphere to make **carbonic acid**, the most important (arguably, see below) in weathering. Carbonic acid is responsible for dissolving limestone to make caves, and often for the damage on old limestone and
marble gravestones. Human-induced “acid rain” is many times more acidic, and thankfully, a much more rare factor in chemical weathering.

4. **Organisms** - The chemical effect of organisms on rocks has only recently become well known to scientists, and is now thought to play a major role in chemical weathering. Roots of plants, fungi, and lichens produce organic acids that help dissolve minerals in rocks, freeing nutrients they need for growth and reproduction. Many forms of bacteria are now known to actually eat minerals!

**Mechanical and chemical weathering work together.** Mechanical weathering speeds up chemical weathering by increasing the surface area for chemical reactions to take place. Chemical weathering weakens or dissolves parts of a rock, allowing subsequent physical weathering to be more effective.

b. **Describe the composition of soil and explain how it formed. (Chapter 2, Section 2)**

Soil is sediment that has undergone changes at the surface of the Earth, including reaction with rainwater and the addition of organic material, so that it can support the growth of plant life. Soil is composed of rock particles, minerals, decayed organic matter, air, and water.

Soil begins to form as exposed bedrock or loose sediment is weathered. **Soil forms by three processes** occurring at or just below the surface of the Earth:

1. Life forms (animals, plants, microbes, fungi) interact with sediment, absorbing and releasing nutrients;
2. Rainwater percolates downwards through sediments, moving chemicals and materials from upper layers to deeper layers, and dissolving some minerals and precipitating new ones; and
3. Burrowing organisms churn up the soil and incorporate organic matter from the surface.

The second process, percolation of rainwater, is the most important in terms of transporting substances and materials to create the distinct zones characterizing a **soil profile**. Near the surface (in what is known as the **zone of leaching**), rainwater dissolves ions and picks up fine sediment. As the water moves downward, it carries the ions and sediment along with it. Farther down, in the **zone of accumulation**, new minerals form from the dissolved ions and other components of the sediment and the water leaves behind the fine sediment.

These processes together produce four main layers or **horizons** in a soil:

1. The uppermost layer (the “O” or organic horizon) consists almost entirely of humus, or partially decayed organic matter, and the abundant organic matter gives it a dark color.
2. Below the O-horizon is the A-horizon, which lies within the zone of leaching and is usually lighter and has less organic matter than the overlying portion. The O and the A-horizon are sometimes collectively called the **topsoil**, and represent the zone of leaching.
3. Beneath the A-horizon is the B-horizon, which corresponds to the zone of accumulation and is also called the **subsoil**. The B-horizon is where ions precipitate to form new minerals and fine sediment (clay) collects; often it appears reddish because of iron-oxide containing minerals and the lack of organic matter.
4. Below the B-horizon is the C-horizon, which contains partially weathered bedrock or sediment, grading downward into unweathered bedrock or sediment.

The **presence, thickness, and chemical composition** of soil horizons vary greatly from place to place. **Five major factors determine soil thickness and composition:**
1. **Parent material**, the kind of rock or sediment underneath the soil; parent material affects the nutrients in the soils (for example, soil formed on the rock basalt is richer in iron than soil formed on granite). Soils generally develop faster on unconsolidated sediment than on bedrock, as more surface area is available for weathering to act.

2. **Climate** variables, in particular temperature and rainfall, are very important factors controlling the rate of chemical reactions.
   a. As temperature increases, the rate of chemical reactions increases. Thus, soils in polar regions are generally not very fertile because humus takes a very long time to form, whereas tropical rain forest soils are infertile because organic matter decays faster than can accumulate as humus.
   b. Water is very important in most chemical weathering reactions, and controls the amount and type of life present; as rainfall increases, the rate of chemical reactions increases. It’s a delicate balance though – too much rain and most nutrients are completely leached out of the soil.

3. **Slope steepness or topography** - Soil on steep slopes tends to be lost downhill faster than it forms, and so is usually relatively thin.

4. **Time** - Soil takes time to develop (usually hundreds to millions of years), so young soils tend to be thin and more poorly developed.

5. **Vegetation** - Different plants extract and add different nutrients in different amounts, produce different quantities of organic matter, and have root systems extending shallowly to deeply.

c. **Identify ways soil is lost or destroyed and explain the importance of soil conservation.** (Chapter 2, Section 3)

   “Soil is one of Earth’s most valuable resources because everything that lives on land depends directly or indirectly on soil.”

Soil suitable for human agriculture developed only in limited areas, and takes time to form (geologic time scale).

Soil is lost through erosion by wind or water. Some farming practices help to limit soil erosion:

1. Contour plowing
2. Conservation plowing
3. Limit size of herd of grazing cattle
4. Crop rotation
5. Conservation buffers
d. **Name and describe processes that wear down the Earth's surface.** (Chapter 3, Section 1)

**Erosion** - processes by which sediment is removed from where it was weathered

**Weathering, erosion, and deposition** act together to wear down Earth’s surface, and build up landforms.

Agents (processes) of erosion:
1. Gravity – mass movement
2. Water (rivers and the ocean)
3. Wind
4. Ice

**e. Explain gravity as a force that affects erosion.** (Chapter 3, Section 1)

**Mass movement** – gravitationally caused transport of rock, soil, snow, and ice downhill

Mass movements can be slow (like slump or creep) or very fast and dangerous (like landslides and mudslides),

How it works: mass movements are triggered when the force holding up rocks, sediments, or hillsides is overcome by the force pulling them downwards.

A simplified example: a rectangular block resting on a slope
1. Downward-pulling forces can be summed to the **downslope force**
2. Forces holding up materials can be summed into the **resistance force**
3. The balance between the downslope and resistance forces determines movement of the block. As long as the resistance force is greater than the downslope force, the block remains stable; if the downslope force is greater than the resistance force, the block becomes unstable on the slope and will move downwards.

The downslope force is primarily controlled by the angle of the slope and the force of gravity – **the steeper the slope, the greater the downslope force.** The resistance force is caused by a number of variables: chemical bonds in mineral crystals, cement (the mineral glue holding sedimentary rocks together), the interlocking crystals of metamorphic and igneous rocks, friction between a block of bedrock and the slope, interlocking of mineral and rock grains in loose or unconsolidated sediment, electrical charges holding soil in place, and surface tension holding damp soil together are all components of the resistance force. Water can act to hold loose sediment together – as in the building of sand castles with damp sand, or it can provide lubrication to the slope surface and allow huge pieces of a hillside to detach after a particularly soaking rain.
Angle of repose:
Loose debris or unconsolidated sediment (sand, gravel) tends to pile up and form the steepest slope it can without collapsing (this is particularly easy to observe in sand dunes.) The angle of this slope is known as the **angle of repose**, and for dry materials it typically is between 30 and 45 degrees.

Three factors play a large role in determining the value of the angle of repose:
1. Shape of the material (rounded or angular),
2. Size of the material (clay, sand, gravel, and larger),
3. Amount of water present.

In general, the angle increases (makes a steeper slope) from small size particles to larger particles and increases as particles become more irregularly shaped. Water is a more complex variable, and sand castles again provide a useful example: with a small amount of water added to sand, a person can build a really steep slope – maybe even greater than 90 degrees, but if the sand becomes too wet, the whole pile will collapse to flat puddle.

Types of mass movement:
1. **Creep** – gradual downslope movement of sediment and soil through seasonal freezing and thawing (tilts roads, trees, fences, etc.)
2. **Slump** – curved block of sediment and soil detaches as a unit and moves downhill; often triggered by heavy rainfall and a weak surface
3. **Landslide** – sudden movement of rock and debris down a slope (very fast – up to 300km/hr)
4. **Mudflow** – water mixes with soil and sediment to make a slurry that moves downhill (fast – up to 100km/hr)

### Combined

| f. | Explain water erosion and describe features formed by it. (Chapter 3, Section 2) |
| g. | Describe land features formed by sediment. (Chapter 3, Section 2) |
| h. | Explain how sediment enters moving water and list factors that affect water's ability to erode and carry sediment. (Chapter 3, Section 3) |

**Water is the predominant agent of erosion on the Earth’s surface – even in deserts.**

Runoff – water moving over the land surface

Sheetwash/sheet erosion – runoff moving in a thin film over the surface

Channel – where sheetwash moves faster, it scours a groove; much of the work of running water takes place in stream channels
Controls on runoff:
1. Amount of rain
2. Vegetation – amount and type
3. Soil type
4. Topography
5. Land use

Anatomy of a stream:
Stream channel/ trunk stream – “river”
Tributary – smaller channel joining trunk stream
Drainage basin/watershed – land area from which a river and all its tributaries collect their water
Drainage divide – topographically higher area separating drainage basins (ex. Continental Divide)
Floodplain – flat area that is underwater in flood conditions
Meander – sinuous curve in the channel
Oxbow lake – meander that is cut off from the channel (ex. Carter Lake)
Bar – region of sediment deposited by the river
Island – emergent bar
Bed – base of a stream channel

Types of streams:
Caveat: most rivers change their configuration along their course
1. Meandering – characterized by a single primary channel, broad floodplain underlain by soft substrate; fairly low slope (flat), usually fine sediment present, moderate sediment load (ex. Elkhorn, Mississippi, modern Missouri)
2. Braided – characterized by multiple channels separated by islands (braided appearance); often form when steeper slope; high sediment load, sandy to gravelly, very wide and shallow (classic example: Platte)

Features of erosion:
1. Valleys
2. Waterfalls
3. Floodplains
4. Meanders
5. Oxbow lakes

Features of deposition:
1. Bars
2. Floodplain (especially soil)
3. Alluvial fan – cone-shaped deposit where steep mountain stream meets flatter plain
4. Delta – deposit of sediment where river meets still water body (ocean or lake)

The force of gravity allows flowing water to do work – erosion and sediment transport.

How sediment is eroded:
1. Mass movement
2. Runoff
3. Abrasion – sediment being transported knocking against the stream bed and channel sides

Sediment transported in a stream is the sediment load.

Types of load:
1. Bed load – sediment bouncing or rolling along the bed
2. Suspended load – silt or clay (fine sediment) that swirl along with the water without settling to the bed (most sediment is suspended in most rivers – muddy appearance)

3. Dissolved load – dissolved minerals

The amount of sediment a river can carry (capacity) and the maximum sediment size a river can carry (competence) increases with flow velocity.

Factors affecting flow velocity (and sediment load):
1. Slope – steeper slope, increased flow velocity
2. Flow volume – more water, increased velocity
3. Streambed shape – greater wetted perimeter (area stream contacts the bed), the greater the frictional force slowing the water + sediment down
4. Location in stream channel – in a curved channel, the water moves fastest along the outside curve and slower along the inside curve.

In general:
1. Sediment is transported from higher elevations to lower elevations (downstream).
2. Sediment is transported from the outside curve of meanders (cut bank) to the inside curve (point bar) – fastest-moving current erodes, slower currents drop sediments.
3. Faster velocity = greater capacity and competence.
4. Deeper, narrower streams flow faster than shallower, wider ones.

i. Name and describe two types of glaciers and ways they erode land. (Chapter 3, Section 4)

Types of glaciers:
1. Mountain or alpine glaciers – exist in or adjacent to mountainous regions
   a. Topographical features control the shape
   b. Slope of substrate controls flow direction
2. Continental glaciers or ice sheets – vast layers of ice spread over thousands of kilometers
   a. Shape controlled by large-scale topographic features
   b. Flow outwards in all directions from thickest point

Formation of a glacier:
1. Winter snow does not entirely melt away in summer for many successive years
2. Sufficient snowfall for large amount to accumulate
3. Slope must be gentle enough for snow to accumulate

Glacial ice constantly flows downhill, like a very slow river. Glaciers advance when the rate of ice accumulation is greater than the rate of melting. Glaciers retreat when the rate of melting exceeds the rate of accumulation. Retreating glaciers don’t flow uphill!

Glaciers erode land by:
1. Plucking – rock fragments freeze to bottom of glacier and are broken off
2. Plowing – flowing ice bulldozes and moves loose sediment
3. Abrasion – sediment embedded in the glacier base grind away at the substrate (produces very fine sediment, polished and gouged surfaces on bedrock)

j. Explain how glaciers deposit sediments and the role of glaciers in the Earth's history. (Chapter 3, Section 4)

Glacial deposits are left when a glacier melts.
Glacial deposits:
1. Till - sediment deposited beneath or at the toe of the glacier; characterized by sediment of many different sizes (unsorted)
2. Moraine – ridge of till left at the edges of a glacier
3. Glacial erratics – boulders dropped by a glacier; recognizable because rock type can be entirely different from local bedrock
4. Kettle lakes– lakes left when chunks of glacial ice fell off the glacier and were buried in till
5. Drumlín – streamlined hill of till with gentle downstream slope and steeper upstream slope
6. Esker – snake-like ridges of sand left when sediment fills meltwater tunnels at the base of a glacier

Many ice ages have occurred in the past; most seem to have been caused by periodic variations in characteristics of Earth’s orbit that change the balance of solar radiation. They are not necessarily associated with decreases in global air temperature.

Continental glaciation associated with the Pleistocene ice age changed the topography and landforms of much of North America (including carving the Great Lakes, producing tons of fine sediment later transported by the wind and deposited in thick layers (loess), changing the course of most major rivers in North America), and changed the climate drastically, causing numerous extinctions of plants and animals. The ice was such a heavy mass that the surface of the Earth sank and is still rebounding back.

Past glaciations have had similar impacts, some of them much greater in magnitude.

k. **Identify how ocean waves get their energy and explain how waves shape landforms and change coastlines.** *(Chapter 3, Section 5)*

Ocean waves get their energy from wind blowing across the water’s surface. Individual water molecules don’t move forward along with the wave, but follow a circular path.

Wave refraction - waves approaching land may be oriented at a large angle with respect to the shoreline, but they bend as they approach to about a 5-degree angle at the shore. The part of the wave that touches bottom slows down first, and the rest of the wave catches up – the water bends to be nearly parallel to the shore.

Wave refraction focuses erosive energy at headlands, the part that sticks out farther, to even out shorelines.

Erosion by waves:
1. Impact – waves smashing against the shore
2. Abrasion – sediment carried by the wave scrapes and smashes against rock and sediment

Deposition by waves:
1. Beach – sediment dropped as waves reach the shore
2. Longshore drift – wave refraction (waves hit at slight angle) causes sediment to move slightly sideways along the beach as wave comes in; gravity causes the water + sediment to flow straight back into the ocean – sediment moves in a zigzag pattern, with net movement sideways.
3. Spit – beach projecting into the water; form by deposition by longshore drift.