ITEM SPECIFICATIONS
8TH GRADE
OSAS SCIENCE TEST

2014 Oregon Science Standards (NGSS)

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Introduction

This document presents *item specifications* for use with the Next Generation Science Standards (NGSS). These standards are based on the Framework for K-12 Science Education. The present document is not intended to replace the standards, but rather to present guidelines for the development of items and item clusters used to measure those standards.

The remainder of this section provides a very brief introduction to the standards and the framework, an overview of the design and intent of the item clusters, and a description of specifications that follow. The bulk of the document is composed of specifications, organized by grade and standard.

Background on the framework and standards

The Framework for K-12 Science Education is organized around three core dimensions of scientific understanding. The standards are derived from these same dimensions:

Disciplinary Core Ideas

The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.

Science and Engineering Practices

The practices are what students **do** to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs (Science and Engineering Practices) reflect the major practices that scientists and engineers use to investigate the world and design and build systems.

Cross-Cutting Concepts

These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.

There is substantial overlap between and among the three dimensions

For example, the cross-cutting concepts are echoed in many of the disciplinary core ideas. The core ideas are often closely intertwined with the practices. This overlap reflects the nature of science itself. For example, we often come to understand and communicate causal relationships by employing models to make sense of observations. Even within a dimension, overlap exists. Quantifying characteristics of phenomena is important in developing an understanding of them, so employing computational and mathematical thinking in the construction and use of models is a very common scientific practice, and one of the cross-cutting concepts suggests that scientists often infer causality by observing patterns. In short, the dimensions are not orthogonal.

The framework envisions effective science education as occurring at the intersection of these interwoven dimensions: students learn science by doing science; applying the practices through the lens of the cross-cutting concepts to investigate phenomena that relate to the content of the disciplinary core ideas.

Item clusters

Each item cluster is designed to engage the examinee in a grade-appropriate, meaningful scientific activity aligned to a specific standard.

Each cluster begins with a phenomenon, an observable fact or design problem that engages student interest and can be explained, modeled, investigated, or designed using the knowledge and skill described by the standard in question.

What it means to be observable varies across practices. For example, a phenomenon for a performance expectation exercising the a*nalyze data* practice may be observable through regularities in a data set, while standards related to the *development and use of models* might be something that can be watched, seen, felt, smelled, or heard.

What it means to be observable also varies across grade levels. For example, elementary-level phenomena are very concrete and directly observable. At the high school level, an observation of the natural world may be more abstract: for example, "observing" changes in the chemical composition of cells through the observation of macroscopic results of those changes on organism physiology, or through the measurement of system- or organ-level indications.

Content limits refine the intent of the performance expectations and *provide limits* on what may be asked of items in the cluster to structure the student activity. The content limits also reflect the disciplinary core ideas learning progressions that are present in the K-12 Framework for Science Education.

The task or goal should be explicitly stated in the stimulus or the first item in the cluster: statements such as "In the questions that follow, you will develop a model that will allow you to identify moons of Jupiter," or "In the questions below, you will complete a model to describe the processes that lead to the steam coming out of the teapot."

Whereas item clusters have been described elsewhere as "scaffolded," they are better described as providing structure to the task. For example, some clusters begin with students summarizing data to discover patterns that may have explanatory value. Depending on the grade level and nature of the standard, items may provide complete table shells or labeled graphs to be drawn, or may require the student to choose what to tabulate or graph. Subsequent items may ask the student to note patterns in the tabulated or graphed data and draw on domain content knowledge to posit explanations for the patterns.

These guidelines for clusters do not appear separately in the specifications. Rather, they apply to all clusters.

Structure of the cluster specifications

The item cluster specifications are designed to guide the work of item writers and the review of item clusters by stakeholders.

Each item cluster has the following elements:

- The text of the performance expectations, including the practice, core idea, and cross-cutting concept.
- Content limits, which refine the intent of the performance expectations and provide limits of what may be asked of examinees. For example, they may identify the specific formulae that students are expected to know or not know.
- Vocabulary, which identifies the relevant technical words that students are expected to know, and related words that they are explicitly not expected to know. Of course, the latter category <u>should not be considered exhaustive</u>, since the boundaries of relevance are ambiguous, and the list is limited by the imagination of the writers.
- Sample phenomena, which provide some examples of the sort of phenomena that would support effective item clusters related to the standard in question. In general, these should be guideposts, and item writers should seek comparable phenomena, rather than drawing on those within the documents. Novelty is valued when applying scientific practices.
- Task demands comprise the heart of the specifications. These statements identify the types of items and activities that item writers should use, and each item written should be clearly linked to one or more of the

demands. The verbs in the demands (e.g., select, identify, illustrate, describe) provide guidance on the types of interactions that item writers might employ to elicit the student response. We avoid explicitly identifying interaction types or item formats to accommodate future innovations and to avoid discouraging imaginative work by the item writers. [*Task demands have been removed from this version of the document to prevent the disclosure of secure item content*.]

- For each cluster we present, the printed documentation includes the cluster and its linkage to the practice and cross-cutting concept identified in the performance expectation.

Performance Expectation MS-ESS1-1

Develop and use a model of the Earth-Sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and the seasons.

Dimensions

Developing and Using Models

- Develop and use a model to describe the phenomena.

ESS1.A: The Universe and Its Stars

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

ESS1.B: Earth and the Solar System

- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth over the year.

Patterns

- Patterns can be used to identify cause and effect relationships.

Clarifications and Content Limits

Content Clarification:

- Examples of models can be physical, graphical, or conceptual.

Assessment Content Limits:

- Students do not need to know Earth's exact tilt; perigee and apogee; sidereal and synodic periods; umbra and penumbra (the term "shadow" should be used); times of moonrise and moonset; precession; exact dates of equinoxes and solstices (but knowledge of the months in which they occur is reasonable to assess).

Science Vocabulary Students Are Expected to Know

- Sun
- Earth
- moon
- shadow
- orbit
- axis
- planet
- satellite
- full moon
- new moon
- half moon

Science Vocabulary Students are Not Expected to Know

- perigee
- apogee
- sidereal period
- synodic period
- synodic month
- umbra
- penumbra
- precession
- equinox
- solstice
- ecliptic
- waxing
- waning
- gibbous
- first quarter moon
- last quarter moon

Phenomena

Some example phenomena for MS-ESS1-1:

- When observed from Earth over the course of a month, the appearance of the moon changes.
- A full moon occurs in every calendar month. However, an eclipse of the moon does not occur in every calendar month.
- A new moon occurs in every calendar month. However, a total eclipse of the sun is a rare event.
- In the northern hemisphere, July is a summer month. In the southern hemisphere, July is a winter month.

Performance Expectation MS-ESS1-2

Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

Dimensions

Developing and Using Models

- Develop and use a model to describe phenomena.

ESS1.A: The Universe and Its Stars

- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

Systems and System Models

- Models can be used to represent systems and the interactions in a system.

Clarifications and Content Limits

Content Clarification:

- Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy, and controls orbital motions within them.
- Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state.

Assessment Content Limits:

- Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.
- Students do not need to know: the mathematical formula for calculating force, inertia, and gravity or to perform any computational analysis, to know Kepler's law, or to calculate trajectories.

Science Vocabulary Students Are Expected to Know

- inertia
- gravity
- force
- mass
- weight
- orbit
- Earth
- moon
- names of planets

Science Vocabulary Students are Not Expected to Know

- names of specific moons
- names of space shuttles
- moment of inertia
- Kepler's laws of planetary motion
- black hole
- specific facts about any planets or moons
- computational analysis on any relative motions

Phenomena

Some example phenomena for MS-ESS1-2:

- Satellites orbit Earth but can fall out of orbit (Skylab, UART satellite).
- Halley's Comet can be seen as it travels past Earth every 75-76 years.
- Rings are present around some planets.

Performance Expectation MS-ESS1-3

Analyze and interpret data to determine scale properties of objects in the solar system.

Dimensions

Analyzing and Interpreting Data

- Analyze and interpret data to determine similarities and differences in findings.

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Clarifications and Content Limits

Content Clarification:

- Examples of scale could include size and distance (Astronomical Units [AU] and relative size [using Earth] are acceptable forms of measuring size and distance).
- Examples of properties could include layers, temperature, surface features, and orbital radius.
- Data sources could include Erath and space-based instruments such as telescopes and satellites.

Assessment Content Limits:

- Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects.
- Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius.
- Examples of data include statistical information, drawings and photographs, and models.
- Assessment does not include recalling facts about properties of the planets other solar system bodies.
- Calculations should be simple calculations that do not require a calculator. The level of computation needs to align with 6th grade math standards. Scale comparison (object is X times the mass of Earth, etc.). Astronomical Units are acceptable
- Types of data could include graphs, data tables, drawings, photographs, and models.
- Students do not need to know: Facts about properties of the planets and other solar system bodies, calculations that require a calculator, scientific notation.

Science Vocabulary Students Are Expected to Know

- orbit
- planet
- moon
- asteroid (belt)
- satellite
- terrestrial planet
- gas giant
- planetary rings
- dwarf planet
- sun
- inner planet
- outer planet
- comet

Science Vocabulary Students are Not Expected to Know

- density
- ecliptic
- solar wind
- interstellar medium
- main sequence
- synchronous rotation
- protostar
- protoplanetary disc
- accretion

Phenomena

The phenomena for these PEs are the given data. Samples of phenomena should describe the data magnification. Some example phenomena for MS-ESS1-3:

- Four of Jupiter's moons can be clearly seen through a small telescope under low magnification. These moons appear as tiny dots arranged around Jupiter.
- Close-up pictures from the New Horizons mission provided new evidence about the dwarf planet, Pluto, which was not able to be gathered by distant observations and calculations (surface features, scale).
- The New Horizons mission revealed a previously unknown structure on Pluto, the Tombaugh Region.
- The sun and the moon appear as approximately the same size in the sky, but the sun is vastly larger than the moon (scale).
- Even though the moon is infinitesimally smaller than the sun, the entire sun is blocked from view on Earth during a solar eclipse (scale).

Performance Expectation MS-ESS1-4

Construct a scientific explanation based on evidence from rock strata for how the geologic timescale is used to organize Earth's 4.6-billion-year-old history.

Dimensions

Constructing Explanations and Designing Solutions

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

ESS1.C: The History of Planet Earth

- The geological time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.

Scale, Proportion and Quantity

- Time, space, and energy phenomena can be observed at various scales, using models to study systems that are too large or too small.

Clarifications and Content Limits

Content Clarification:

- Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history.
- Example of Earth's major events could range from being geologically recent (e.g., the most recent glacial period or the earliest fossils of Homo sapiens) to geologically very old (e.g., the formation of Earth or the earliest evidence of life).
- Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant instances of volcanic activity.

Assessment Content Limits:

- Assessment does not include recalling the names of specific periods or epochs and events within them. Students do not need to know the types of unconformities (e.g., disconformity, but they should know that unconformities exist).

Science Vocabulary Students Are Expected to Know

- erosion
- weathering
- fossil
- ancient
- prehistoric
- layer
- formation
- strata
- mineral
- sedimentary
- sediment
- metamorphic
- volcanic
- superposition
- cross-cutting
- fault
- fold
- geology
- geological

Science Vocabulary Students are Not Expected to Know

- radioactive dating
- bio-geology
- geobiology
- relative dating
- numerical dating
- absolute dating
- carbon dating
- radiometric dating
- igneous
- stratigraphy
- biostratigraphy
- chronostratigraphy
- sequence
- sequence stratigraphy
- bed, lamina
- paleoenvironment
- paleoecology
- paleomagnetic

Phenomena

Some example phenomena for MS-ESS1-4:

- A very distinct clay layer tops the Hell Creek Formation in Montana. Below this layer, the Hell Creek is rich in dinosaur fossils; above the layer, no dinosaurs are found.
- The landscape of Cape Cod, Massachusetts, is almost entirely small hills of sand and gravel. However, a hole drilled 500 feet into the ground will hit hard metamorphic rock.
- In Box Canyon in Ouray, Colorado, metamorphic rocks that are standing vertical are capped by sedimentary rocks that are lying flat.
- The St. Peter Sandstone is a very white sandstone rock layer exposed in many places in the mid-western United States. The St. Peter is very uniform in appearance but the rock layer sits on top of different kinds of rocks in the North than it does in Missouri.

Performance Expectation MS-ESS2-1

Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

Dimensions

Developing and Using Models

- Develop and use a model to describe the phenomena.

ESS2.A: Earth's Materials and Systems

- All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. The energy is derived from the sun and Earth's hot interior, the energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, including the atomic scale.

Clarifications and Content Limits

Content Clarification:

- Emphasis is on the processes of melting, crystallization, weathering, deposition, sedimentation, and deformation, which act together to form minerals and rocks through the cycling of Earth's matter.

Assessment Content Limits:

- Assessment does not include the identification and naming of minerals.
- Students do not need to know: specific processes of chemical or biochemical weathering; rock phase diagrams; mineral stability diagrams; mineral weathering orders; mineral crystallization orders (e.g., Bowen's Reaction Series); mineral metamorphism orders/temperatures/pressures/stabilities; rock metamorphism zones; specific processes that drive the tectonic engine (e.g., slab pull; ridge push).

Science Vocabulary Students Are Expected to Know

- sun
- heat
- temperature
- flow
- collide
- heat conduction
- transform
- transport
- heat transfer
- thermal
- heat radiation
- thermal energy
- heat convection
- rain
- snow
- ice
- precipitation
- volcanic eruption
- atmosphere
- chemical
- freeze/thaw
- weathering
- erosion
- sediment
- deposition
- rock cycle
- ice wedge
- chemical change
- physical change
- fault
- fold
- igneous rock
- metamorphic rock
- sedimentary rock
- volcanic rock
- plate tectonics
- crust
- mantle
- outer core
- inner core

Science Vocabulary Students are Not Expected to Know

- biogeology
- geobiology
- geochemistry
- biogeochemistry
- rock sequence
- convection current
- mountain building
- geochemical cycle
- tectonic uplift
- accretionary wedge
- accretionary prism

Phenomena

Some example phenomena for MS-ESS2-1:

- Lava from an erupting volcano in Hawaii flows across a road. The molten material is so hot that it emits light. Several months later, the material covering the road is hard, black rock.
- A mountain is capped by metamorphic rock. Many cracks crisscross the rock. Rainwater often fills the fractures, freezing when temperatures drop. Over the years, the fractures become wider.

Performance Expectation MS-ESS2-2

Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Dimensions

Constructing Explanations and Designing Solutions

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.

ESS2.A: Earth's Materials and Systems

- The planet's systems interact over scales that rage from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

ESS2.C: The Roles of Water in Earth's Surface Processes

- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events.
- Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind.
- Emphasis is on geoscience processes that shape local geographic features, where appropriate.

Content Limits:

- Students are expected to know all of the components/processes of the rock cycle but not specific rock or mineral names.
- Students do not need to know Endogenic or exogenic systems, specific intervals of the Geological Time Scale by name, specific volcano types (shield, effusive, composite, etc.).

Science Vocabulary Students are Expected to Know

- earthquake
- volcanic eruptions
- core
- crust
- mantle
- wind
- temperature
- pressure
- continent
- erosion
- weathering
- million, billion, years
- magma
- lava
- igneous
- sedimentary
- metamorphic
- mineral
- meteor
- crater
- mountain
- plate tectonics
- ocean
- continental drift
- subduction zone
- divergent boundary
- convergent boundary
- hot spot
- fault
- tsunami
- hurricane
- tornado
- fracture
- folding
- Compressing
- sea floor spreading
- layer
- ridge
- rock cycle
- trench
- plateau
- slope
- landslides
- floods
- caves

Science Vocabulary Students are Not Expected to Know

- Endogenic system
- exogenic system
- radiometric dating
- originally horizontality
- superposition
- uniformitarianism
- primordial
- epoch, eon
- period
- liquification
- mohorovicic discontinuity (Moho), seismic waves
- seismograph
- Richter scale
- fumaroles
- mofettes
- solfataras
- Caledonian era
- Variscan era
- alpine era, massif
- graben
- monolith
- monadnock
- nappe system
- isostasy
- pluton
- batholith
- stratigraphy
- lithification
- evaporite
- hydrothermal
- relief
- topography
- continental shield
- terrain
- anticline
- syncline
- strike-slip fault
- horst, orogenesis
- tephra
- caldera

Phenomena

Some example phenomena for MS-ESS2-2:

- A hillside in Oregon experiences an intense rain storm. At the end of the storm, part of the hillside collapses, covering a road with mud and debris.
- In Northern Arizona, there is a large circular depression.
- In southeastern Pennsylvania, the landscape is dotted with a number of irregular holes that lead to caves.
- When viewed from orbit, the coastline the eastern south line of South America and the Western Coast of Africa look as though they were joined together, similar to a jigsaw puzzle.

Performance Expectation MS-ESS2-3

Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of past plate motions.

Dimensions

Analyzing and Interpreting Data

- Analyze and interpret data to provide evidence for phenomena.

ESS1.C: The History of Planet Earth

- Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (secondary)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

Patterns

- Patterns in rates of change and other numerical relationships can provide information about natural systems.

Clarifications and Content Limits

Assessment Content Limits:

- Paleomagnetic anomalies in oceanic and continental crust are not assessed.
- Students do not need to know: specific chemical makeup of the crust, mantle, and core; specific rocks within major categories (e.g., basalt, amphibolite, granite); mineral crystallization orders (e.g., Bowen's Reaction Series), mineral melt orders

Science Vocabulary Students Are Expected to Know

- crust
- mantle
- core
- convection
- density
- plate tectonics
- earthquake
- geosphere
- element
- continental
- oceanic
- plate
- upwelling
- cell (as in convection)
- trench
- subduction
- ridge
- volcanic
- sedimentary
- fault
- extension
- volcanic rock
- sedimentary rock
- metamorphic rock
- ridge
- earthquake
- hotspot

Science Vocabulary Students are Not Expected to Know

- block (as in fault)
- accretionary wedge
- accretionary prism
- mantle composition
- stress (tectonic)
- strain (tectonic)
- normal fault
- transform fault
- thrust fault
- reverse fault
- foot wall
- hanging wall
- felsic
- mafic
- ultramafic

Phenomena

Some example phenomena for MS-ESS2-3:

- There are volcanoes on all of the Hawaiian Islands, but only volcanoes on the southeastern most island, Hawaii, are active today.
- Earthquakes are very commonly felt on the islands of Japan.
- The coasts of different continents appear to fit together like two jigsaw puzzle pieces. Identical fossils of certain plants and animals are preserved in rocks found along both coasts.

Performance Expectation MS-ESS2-4

Develop a model to describe how the cycling of water through Earth's systems is driven by energy from the sun, gravitational forces, and density.

Dimensions

Developing and Using Models

- Develop a model to describe unobservable mechanisms.

ESS2.C: The Roles of Water in Earth's Surface

- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- Global movements of water and its changes in form are propelled by sunlight and gravity.

Energy and Matter

- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

Clarifications and Content Limits

Clarification Statements:

- Examples of models can be conceptual or physical.
- Content emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle.
- Practice emphasis is on developing a model and being able to explain reasoning behind choices made relative to the developing or changing of a model. While a few interactions can be about using the model, the focus should not be on using the model or designing an experiment using the model. Any stand-alone items written to this PE should be centered on the development of models.

Content Limits:

- A quantitative understanding of the latent heats of vaporization and fusion is not assessed.
- Students do not need to know:
    - Cloud types
    - Types of aquifers and components of aquifers
    - Concepts of subsurface water flow and transmissivity (e.g., permeability/porosity of the substrate and interactions with fluids; behaviors of subsurface fluids under confinement (both quantitatively and qualitatively).

Science Vocabulary Students are Expected to Know

- precipitation
- transpiration
- evaporation
- condensation
- crystallization
- density
- runoff
- temperature
- air pressure
- particle
- atmosphere

Science Vocabulary Students are Not Expected to Know

- hyporheic zone
- aquifer
- aquitard
- aquiclude
- subsurface flow
- sublimation
- vadose zone
- unsaturated zone
- water table
- phreatic surface
- capillary fringe
- saturated zone
- phreatic zone
- drainage basin
- watershed
- porosity
- permeability
- transmissivity
- recharge
- recharge area
- discharge
- discharge area
- potentiometric surface
- hydraulic head
- lithosphere
- biosphere
- hydrosphere
- cryosphere

Phenomena

Some example phenomena for MS-ESS2-4:

- When driving over a bridge on a cool morning, you see fog over the river but not over the land.
- Morning fog and mist soon disappears after the sun rises on a clear day.
- The Blue Mountains have snow that melts (eventually) into the Columbia River to the John Day Dam.
- In the Iowa cornfields in the summer, a dense dome of humidity forms over the cornfields.

Performance Expectation MS ESS2-5

Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.

Dimensions

Planning and Carrying Out Investigations

- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

ESS2.C: The Roles of Water in Earth's Surface Processes

- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

ESS2.D: Weather and Climate

- Because these patterns are so complex, weather can only be predicted probabilistically.

Cause and Effect

- Cause and Effect relationships may be used to predict phenomena in natural or designed system.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on how air masses flow from regions of high pressure to low pressure, causing weather (defined by temperature, pressure, humidity, precipitation, and wind) at a fixed location to change over time, and how sudden changes in weather can result when different air masses collide.
- Emphasis is on how weather can be predicted within probabilistic ranges.
- Examples of data can be provided to students (such as weather maps, diagrams, and visualizations) or obtained through laboratory experiments (such as condensation).

Content Limits:

- Weather incidents internal to air masses are excluded because the focus is on the interfaces between large scale air masses.
- Students do not need to know: Names of the various types of clouds, weather symbols used on weather maps, weather symbols used on reports from weather stations. A legend will be included on weather maps.

Science Vocabulary Students Are Expected to Know

- density
- temperature
- pressure
- humidity
- precipitation
- wind speed
- wind direction
- air mass
- cold/warm front
- condensation
- evaporation
- latitude
- altitude
- flow
- thermometer
- barometer
- anemometer
- relative humidity

The listing of devices is supported by evidence statement 3.a "Students describe the tools and methods used in the investigation." This also implies inclusion of measurement units- degrees Fahrenheit, degrees Celsius, atmospheric pressure units (inches/millimeters of mercury, hectopascals)

Science Vocabulary Students Are Not Expected to Know

- cumulus
- cumulonimbus
- cirrus
- stratus
- alto- and nimbo- as modifiers
- cyclone
- anticyclone
- isobar
- isotherm
- pressure gradient
- Coriolis force*
- hygrometer
- psychrometer (humidity meters)
- jet stream
- dew point
- stationary front
- occluded front

*Coriolis force IS covered in PE MS-ESS2-6

Phenomena

Some example phenomena for MS-ESS2-5:

- One fall day starts out warm and fairly still. The wind picks up and the temperature drops and it begins to rai.
- The flag outside a school has been resting against the flagpole, unmoving all morning. In the early afternoon, it starts flapping in the wind. At sunset, rain begins.
- Fall days were chilly, then the temperature warmed up for a few days.
- A tornado formed in the Pacific Ocean near Oregon.

Performance Expectation MS ESS2-6

Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Dimensions

Developing and Using Models

- Develop and use a model to describe phenomena.

ESS2.C: The Roles of Water in Earth's Surface Processes

- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on how patterns vary by latitude, altitude, and geographic land distribution.
- Emphasis of atmospheric circulation is on the sunlight-driven latitudinal banding, the Coriolis Effect, and resulting prevailing winds; emphasis of ocean circulation is on the transfer of heat by the global ocean convection cycle, which is constrained by the Coriolis Effect and the outlines of continents.
- Examples of models can be diagrams, maps and globes, or digital representations.

Content Limits:

- Students do not need to know: names of specific winds, different cloud types (cumulus, cirrus etc.), names of specific ocean currents, or perform any quantitative analyses based on the Coriolis Effect, mathematical calculations beyond trends, or measurements of central tendency.

Science Vocabulary Students Are Expected to Know

- weather
- climate
- temperature
- atmospheric pressure
- density
- current
- latitude
- altitude
- Coriolis effect
- convection
- condensation
- precipitation
- cloud, water cycle
- air mass circulation
- vegetation
- latitude
- longitude
- rain shadow

Science Vocabulary Students Are Not Expected to Know

- trade winds
- easterlies
- westerlies
- cumulus
- cirrus or other cloud names
- gulf stream
- Labrador
- ocean current names
- UV rays

Phenomena

Some example phenomena for MS-ESS2-6:

- In December 2010, Gary, Indiana, on the southeast shores of Lake Michigan, had approximately 30 inches of snow over a three-day period, whereas Chicago, Illinois, 30 miles away, received barely any snow.
- Onshore and offshore breezes—in the morning, the breeze comes in from the ocean. At night, the breeze is blowing in the opposite direction.
- Wind storms in the Sahara become hurricanes that affect the east coast of North America and the Caribbean, but not the coast of South America.
- The Westerlies vs. The Easterlies and the trade winds—why are these wind patterns banded as you move north from the equator?

Performance Expectation MS-ESS3-1

Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.

Dimensions

Constructing Explanations and Designing Solutions

- Constructing a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

ESS3.A: Natural Resources

- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

Cause and Effect

- Cause-and-effect relationships may be used to predict phenomena in natural or designed systems.

Clarifications and Content Limits

Content Clarification:

- Examples of uneven distribution of resources could include Utah's unique geologic history that led to the formation and irregular distribution of natural resources like copper, gold, natural gas, oil share, silver and uranium.
- Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans.
- Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (location of the burial of past volcanic and hydrothermal activity associated with subduction zones), and soil (location of active weathering and/or deposition of rock)

Science Vocabulary Students Are Expected to Know

- agriculture
- biosphere
- conservation
- consumption
- cost-benefit
- deposition
- distribution
- efficient
- energy source
- geologic process
- geologic trap
- geoscience
- groundwater
- hydrothermal
- impact interdependence
- marine sediment
- metal ore
- mineral
- organic
- petroleum
- volcanic rock
- regulation
- renewable energy
- subduction zone

Science Vocabulary Students are Not Expected to Know

- bitumen
- harvesting of resources
- viscous
- natural gas
- oil shale
- sustainability
- tar sand
- extract
- irreversible

Phenomena

Some example phenomena for MS-ESS3-1:

- Large surface deposits of sand and gravel are much more common in Massachusetts than they are in Virginia.
- Diamonds are found on the ground in a State Park in southwestern Arkansas.
- Bauxite, an Aluminum ore, and fossil tree roots are found in an exposure in Queensland, Australia.
- A well is drilled and water is discovered near Colorado Springs, CO. Ten miles to the Southwest, another well is drilled to the same depth and no water is discovered.

Performance Expectation MS-ESS3-2

Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

Dimensions

Analyzing and Interpreting Data

- Analyze and interpret data to determine similarities and differences in findings.

ESS3.B: Natural Hazards

- Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces, can help forecast the locations and likelihoods of future events.

Patterns

- Graphs, charts, and images can be used to identify patterns in data.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable.
- Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods).
- Examples of data can include the locations, magnitudes, and frequencies of the natural hazards.
- Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).

Content Limits:

- Analysis may include recognizing patterns in data, identifying periodicity, straightforward mathematical comparisons (more, less, faster, slower), examining trends, looking for differences in tabular data, qualitative spatial analysis (e.g., looking at fault lines), recognizing trends and patterns. May include drawing lines of best fit and extrapolating from those lines.
- Analysis should not include regression analysis or calculating correlations.

Science Vocabulary Students are Expected to Know

- accuracy
- air mass
- air mass circulation
- altitude
- atmospheric
- atmospheric circulation
- average
- biosphere
- carbon dioxide
- climate change
- climatic pattern
- condensation
- constrain
- convection cycle
- Coriolis effect
- cyclical
- density
- determinant
- distribution
- latitude
- latitudinal
- longitude
- longitudinal
- mass
- oceanic
- ocean circulation
- orbit
- orientation
- pressure
- probabilistic
- redistribute
- salinity
- solar
- store
- tectonic
- tectonic cycle
- tilt
- time scale
- transfer
- unequal heating of air
- unequal heating of land masses
- unequal heating of oceans
- weather map
- catastrophic
- debris
- development
- economic
- frequency
- geologic
- impact
- interdependent
- magnitude
- mass wasting
- natural process
- reservoir
- satellite

Science Vocabulary Students are Not Expected to Know

- concentration
- electromagnetic
  radiation
- radiation
- sea level

Phenomena

For this performance expectation, the phenomena are sets of data. Those are the observed facts that the kids will look at to discover patterns. Below, we enumerate some of the patterns that might comprise the data sets (phenomena) to be analyzed.

Some example phenomena for MS-ESS3-2:

- A sequence of maps illustrates temperature patterns and occurrence of tornados over the course of the year (to identify variations of tornado risk across regions and also to identify more proximate predictors of tornados).
- A sequence of maps illustrates temperature and humidity patterns and occurrence of hurricanes over the course of the year (to identify variations of hurricane risk across regions and also to identify more proximate predictors of hurricanes).
- Temperature and humidity patterns in the Pacific Ocean can be correlated to the snow pack on Mt. Hood.
- A map of average snowfall in the Great Lakes region shows more snow has fallen in locations nearer to the lakes. Data include surface temperatures, water temperature, wind patterns and snowfall.

Performance Expectation MS-ESS3-3

Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Dimensions

Constructing Explanations and Designing Solutions

- Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progress to include constructing explanations and designing solutions supported with scientific ideas, principles, and theories.
- Apply scientific principles to design an object, tool, process or system.

ESS3.C: Human Impacts on Earth Systems

- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing extinction of other species. But change to Earth's environments can have different impacts (negative and positive) for different living things.

Cause and Effect

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.

Clarifications and Content Limits

Clarification Statements:

- Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact.
- Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the constructions of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as air, water, or land).

Content Limits:

- Students will not describe the relationship between natural resources and sustainability.

Science Vocabulary Students are Expected to Know

- diversity
- societal
- wetland
- agriculture
- biosphere
- development
- fertile
- groundwater
- industry
- material world
- mineral
- river delta
- aquifer
- Earth system
- economic
- human activity
- human impact
- land usage
- levee
- water usage
- consumption

Science Vocabulary Students are Not Expected to Know

- anthropogenic changes
- consumption
- per-capita
- urban development
- biomass
- degradation
- destabilize
- geoengineering
- ozone
- pollutant
- sea level
- stabilize
- waste management
- harvesting of resources
- cost-benefit

Phenomena

Engineering PE's are built around meaningful design problems rather than phenomena.
Some example design problems for MS-ESS3-3:

- Nurdles are small plastic pellets, smaller than a pea. Billions of them are used in creating plastic products. Many fall out of the truck or ship container that they are transported in and end up in oceans where they are mistaken as food by marine animals.
- Glen Canyon Dam is located on the Arizona and behind it sits Lake Powell the second largest reservoir in the United States. Glen Canyon Dam holds back sediment that would naturally replenish downstream ecosystems. The sediment that is trapped behind the dam is filling Lake Powell at a rate of roughly 100 million tons of sediment a year, decreasing the dam's ability to store water
- Farmers in Iowa plow their fields in the spring in order to break up the thick soil and disrupt weeds from growing. The practice of plowing however, causes farmers to lose valuable top soil due to wind erosion.
- In the central North Pacific Ocean there is what is described as a great garbage patch. This large area has high concentrations of plastics, fishing nets, and other debris. This debris is sometimes mistaken as food by marine animals.

Performance Expectation MS-ESS3-4

Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Dimensions

Engaging in Argument from Evidence

- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

ESS3.C: Human Impacts on Earth Systems

- Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise.

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Clarifications and Content Limits

Clarification Statements:

- Emphasize that these resources are limited and may be non-renewable
- Examples of evidence include rates of consumption of food and natural resources such as fresh water, minerals, and energy sources.
- Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.

Content Limits:

- Assessment is limited to one form of consumption and its associated impacts.
- Students do not need to know: mechanisms or details about interior geological processes, quantities and types of pollution released, changes to biomass and species diversity, or changes in land surface use.

Science Vocabulary Students are Expected to Know

- conservation
- recycling
- perishable
- synthetic
- manufactured
- rivers
- lakes
- groundwater
- fertile
- delta
- fossil fuels
- pollution
- composition
- glacier
- mass
- volume
- concentration

Science Vocabulary Students are Not Expected to Know

- tar sands
- oil shales
- agricultural efficiency
- urban planning
- aesthetics
- biomass
- glacial ice volumes
- hydrosphere
- cryosphere
- geosphere
- acidification
- empirical evidence
- polar caps

Phenomena

Some example phenomena for MS-ESS3-4:

- Lake Urmia in Iran was once the nation's largest lake. Today, the lake is 5% as large as it used to be.
- In 1990, much of the tropical rain forests on the Hainan Island were clear-cut to obtain wood, and to create space for plantations. Today, the forests are still smaller and less developed than they were before 1990.
- A coal power plant in Martins Lake, Texas, releases huge clouds of gas into the air every day.
- The open-pit copper mine Ok Tedi Mine in Papua, New Guinea, releases its drainage nearby. Downstream, the rivers turned orange and the fish died.
- Mountains Pike County, Kentucky, has had their mountaintops removed, and are flat on top.
- Over the past 30 years, the Aral Sea in the former Soviet Union has shrunk to less than half its original size.

Performance Expectation MS-ESS3-5

Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

Dimensions

Asking Questions and Defining Problems

- Ask questions to identify and clarify evidence of an argument.

ESS3.D: Global Climate Change

- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as the understanding of human behavior and on applying that knowledge wisely in decisions and activities.

Sustainability and Change

- Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Clarifications and Content Limits

Clarification Statements:

- Examples of factors include human activities (such as fossil-fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity).
- Examples of evidence can include tables, graphs, and maps of global and regional temperatures; atmospheric levels of gases such as carbon dioxide and methane; and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.

Science Vocabulary Students Are Expected to Know

- climate change
- atmosphere
- force
- rotation
- intensity
- physical change
- climate
- glacier
- weather condition
- global
- local
- solar
- natural resource
- natural process
- catastrophic
- cycle
- freeze
- role
- atmospheric composition
- environmental
- pollution
- fossil fuel
- societal
- earth's surface
- renewable resource
- nonrenewable
- oil
- absorb

Science Vocabulary Students Are Not Expected to Know

- climactic pattern
- human activity
- carbon dioxide
- cyclical
- time scale
- concentration
- impact
- magnitude
- atmospheric change
- destabilize
- human impact
- negative
- positive
- consumption
- civilization
- degradation
- pollutant
- sea level
- stable
- long-term
- natural gas

Phenomena

Some example phenomena for MS-ESS3-5:

- A region in the Saint Elias Mountains in Alaska used to be covered by the Plateau Glacier. It is now populated with thick vegetation and a lake.
- On December 14th, 2016, the Deely Power Plant was operating. Its chimney emitted a large cloud of white smoke.
- The Soloman Islands are a group of small islands located in the Pacific Ocean. Five of these islands disappeared in 2016.
- Mount Etna, one of the world's most active volcanoes, erupted in May 2016, delivering plumes of smoke that filled the horizon.

Performance Expectation MS-LS1-1

Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.

Dimensions

Planning and Carrying Out Investigations

- Conduct an investigation to produce data to serve as the basis for evidence that meets the goals of an investigation.

LS1.A: Structure and Function

- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular).

Scale, Proportion, and Quantity

- Phenomena that can be observed at one scale may not be observable at another scale.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on developing evidence that living things are made of cells, distinguishing between living and non-living things, and understanding that living things may be made of one cell or many varying cells.

Content Limits:

Students do not need to know:

- The structures or functions of specific organelles or different proteins
- Systems of specialized cells
- The mechanisms by which cells are alive
- Specifics of DNA and proteins or of cell growth and division
- Endosymbiotic theory
- Histological procedures

Science Vocabulary Students Are Expected to Know

- multicellular
- unicellular
- cells
- tissues
- organ
- system
- organism hierarchy
- bacteria
- colonies
- yeast
- prokaryote
- eukaryote
- magnify
- microscope
- DNA
- nucleus
- cell wall
- cell membrane
- algae, chloroplast(s)
- chromosomes
- cork

Science Vocabulary Students Are Not Expected to Know

- differentiation
- mitosis
- meiosis
- genetics
- cellular respiration
- energy transfer
- RNA
- protozoa
- amoeba
- histology
- protista
- archaea
- nucleoid
- plasmid
- diatoms
- cyanobacteria

Phenomena

Some example phenomena for MS-LS1-1:

- Plant leaves and roots have tiny box-like structures that can be seen under a microscope.
- Small creatures can be seen swimming in samples of pond water viewed through a microscope.
- Different parts of a frog’s body (muscles, skin, tongue, etc.) are observed under a microscope, and are seen to be composed of cells.
- One-celled organisms (bacteria, protists) perform the eight necessary functions of life, but nothing smaller has been seen to do this.
- Swabs from the human cheek are observed under a microscope. Small cells can be seen.

Performance Expectation MS-LS1-2

Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.

Dimensions

Developing and Using Models

- Develop and use a model to describe phenomena.

LS1.A: Structure and Function

- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts; therefore, complex natural structures/systems can be analyzed to determine how they function.

Clarifications and Content Limits

Clarification Statements:

- Emphasize the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.

Content Limits:

- Assessment of organelle structure/function relationships is limited to the cell wall and cell membrane.
- Assessment of the function of the other organelles is limited to their relationship to the whole cell.
- Assessment does not include the biochemical function of cells or cell parts.
- Students do not need to know: protein synthesis, cell division (mitosis), reproduction (meiosis)
- No relation of cell to organism function.

Science Vocabulary Students Are Expected to Know

- eukaryote
- prokaryote
- nucleus
- chloroplast
- mitochondrion
- cell membrane
- cell wall
- diffusion
- osmosis
- photosynthesis
- cellular respiration
- sugar
- DNA
- RNA
- energy
- bacteria
- cytoplasm
- organelle

Science Vocabulary Students Are Not Expected to Know

- golgi
- ribosome
- endoplasmic reticulum
- enzyme
- replication
- mitosis
- meiosis
- glucose
- chromosome
- protein channels
- lysosome
- vacuole
- peroxisome
- thylakoid
- stroma
- granum
- nuclear envelope
- nucleolus
- flagellum
- cytoskeleton
- microvilli
- chromatin
- plasmodesmata
- microfilaments
- microtubules
- fimbriae
- nucleoid
- capsule
- flagella
- nucleoid
- plasma membrane
- cytosol
- phagocytosis
- endocytosis
- cristae

Phenomena

Some example phenomena for MS-LS1-2:

- Skin cells act as a barrier between your insides and the outside.
- Under a microscope, a muscle cell looks different than a skin cell.
- Under a microscope, a root cell looks different than a leaf cell.
- A human sperm cell is smaller than a human egg cell.
- An E. coli bacterium is approximately the same size as the mitochondria of a mammalian lung cell.

Performance Expectation MS-LS1-3

Use argument supported by evidence for how the body is a system of interacting sub-systems composed of groups of cells.

Dimensions

Engaging in Argument from Evidence

- Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.

LS1.A: Structure and Function

- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be part of larger complex systems.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of sub-systems within a system and the normal functioning of those systems.

Content Limits:

- Assessment does not include the mechanism of one body system independent of others.
- Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.

Science Vocabulary Students Are Expected to Know

- organism
- organization
- plant organ
- plant product
- root development
- structure
- organ
- organ system
- cell
- detect
- response
- internal
- internal cue
- internal structure
- life-sustaining functions
- muscular system
- skeletal system
- tissues
- respiration
- respiratory
- vertebra
- vertebrate
- properties
- independent
- role
- development
- anatomy
- aorta
- artery
- automatic
- biceps
- blood
- blood stream
- bone
- bone marrow
- brain
- brain stem
- cerebellum
- invertebrate
- reproduction
- breed
- development
- backbone
- blood
- cerebrum
- circulatory system
- connective tissue
- cornea
- digest
- digestive system
- gland
- growth
- growth rate
- lens
- life
- muscle
- muscle cell
- reflex
- sensory
- skeletal
- heart
- lungs
- heart rate

Science Vocabulary Students Are Not Expected to Know

- destabilize
- excitatory molecule
- feedback mechanism
- hierarchical
- homeostasis
- inhibitory
- molecule
- immune system
- living system
- neural
- organic compound synthesis
- protein structure
- protein synthesis
- regulate
- stabilize
- stomate
- system level
- excretion
- liming factor
- voluntary muscle
- pancreas
- sensory fiber
- sensory nerve
- root development

Phenomena

Some example phenomena for MS-LS1-3:

- After falling and scraping your knee, a scab forms over the wound.
- An elephant’s heart rate is slower than a mouse’s heart rate even though it is much bigger
- A person swallows their food while doing a handstand, but a bird cannot swallow food while hanging upside down.
- When a person hasn’t eaten in a few hours and is hungry, their stomach makes an audible “growling” sound.

Performance Expectation MS-LS1-4

Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

Dimensions

Engaging in Argument from Evidence

- Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation of a model for a phenomenon or a solution to a problem.

LS1.B: Growth and Development of Organisms

- Animals engage in characteristic behaviors that increase the odds of reproduction.
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in a systems can only be described using probability.

Clarifications and Content Limits

Clarification Statements:

- Examples of behaviors that affect the probability of animal reproduction could include: nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding.
- Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth.
- Examples of plant structures could include: bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.

Content Limits:

- Data analysis should be limited to calculations and interpretation of measures of central tendency.
- Students are only expected to understand probability as expected relative frequency.
- Students can be asked to evaluate whether sample data are representative and the limits to which findings can be generalized.
- Data sets can include not only common trends but also outliers and anomalous data points.
- Students do not need to know: Mechanisms or patterns of inheritance, meiosis

Science Vocabulary Students Are Expected to Know

- reproduction
- reproductive
- nest
- herd
- herding
- mate
- mating
- breed
- breeding
- probability
- behavior
- flower
- petal
- seed
- fruit
- nectar
- germinate
- germination
- vocalization
- plumage
- pollination
- pollinate
- pollinator

Science Vocabulary Students Are Not Expected to Know

- symbiosis
- mutualism
- commensalism
- parasitism
- gametophyte
- sporophyte
- carpal
- sepal
- pistil
- anther
- stamen
- ovule
- "alteration of generations"
- Sporangia
- Monoecious
- dioecious

Phenomena

Some example phenomena for MS-LS1-4:

- Spring peepers (*Pseudacris crucifer*) in South Georgia, North Georgia, and Eastern Kentucky begin vocalizing (breeding) at different times of the year. (Lat November in South GA, mid-January in North GA, and February in Eastern KY…
- Female poison arrow frogs lay their eggs in leaf litter. When they hatch, male poison arrow frogs herd the tadpoles onto their backs and transport them to bromeliads, where they develop into adulthood.
- The proportion of trees that are pollinated by insects decreases with latitude (phenomenon would be data tables that illustrate this relationship).
- Wind pollinated trees produce more pollen than animal-pollinated trees (again, data tables would illustrate).
- Ponderosa Pine seed cones are glued shut and only open after a fire (also mesquite plants).
- The Aspen tend to be one of the first plants to emerge after a forest fire.

Performance Expectation MS-LS1-5

Construct a scientific explanation based on evidence for how environment and genetic factors influence the growth of organisms.

Dimensions

Constructing Explanations and Designing Solutions

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

LS1.B: Growth and Development of Organisms

- Genetic factors as well as local conditions affect the growth of the adult plant.

Structure and Function

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be describe using probability.

Clarifications and Content Limits

Clarification Statements:

- Examples of local environmental conditions could include availability of food, light, space, and water.
- Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms.
- Examples of evidence could include a drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.

Content Limits:

- Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.
- Assessment does not include Punnett squares.
- Students do not need to know: epigenetics or variations of gene expression.

Science Vocabulary Students Are Expected to Know

- gene
- genetics
- genome
- genotype
- environment
- growth
- development
- DNA

Science Vocabulary Students Are Not Expected to Know

- epigenetics
- RNA
- gene expression
- photoperiod

Phenomena

Phenomena for this PE should include two groups of a particular organism with one environmental change.
Some example phenomena for MS-LS1-5:

- An orchard contains both full-sized and dwarf apple trees. Individuals of both types of tree grow shorter and produce fewer apples when planted on a dry hillside, and grow taller and produce more apples when planted on the shore of a pond. (i.e., the full apple trees on the hillside are the same size with similar apple production as the dwarf apple trees by the pond).
- Only about 90% of identical twins each have the same height.
- A group of poinsettias and daisies are grown in the same greenhouse. The poinsettias bloom when exposed to ten consecutive hours of light, but the daisies bloom when exposed to 14 consecutive hours of light.
- Burrs are dispersed to different environments by traveling on the fur of mammals. Some seeds from a burr plant drop off into a sunny field, while others drop off into a shady patch of woods. The burr plants that grew in the sun are taller and produced more burrs than those that grew in the shade.

Performance Expectation MS-LS1-6

Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

Dimensions

Constructing Explanations and Designing Solutions

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

LS1.C: Organization for Matter and Energy Flow in Organisms

- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

PS3.D: Energy in Chemical Processes and Everyday Life

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen (secondary).

Energy and Matter

- Within a natural system, the transfer of energy drives the motion and/or cycling of matter.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on tracing movement of matter and flow of energy.
- Students are able to identify relationships between dependent and independent variables.

Content Limits:

- Assessment does not include the biochemical mechanisms of photosynthesis.
- Students do not need to know how to balance chemical equations.

Science Vocabulary Students Are Expected to Know

- glucose
- algae
- consumer
- product
- transform
- transformation
- conservation
- convert
- store
- energy flow
- decomposer
- flow chart
- aquatic
- organic
- phytoplankton
- producer
- reaction
- carbon
- carbon dioxide
- chemical process
- chemical reaction
- molecule
- nutrient
- ecosystem
- energy transfer
- climate change
- moisture
- structure
- internal structure
- organic matter
- stimulus
- tissue

Science Vocabulary Students Are Not Expected to Know

- cellular respiration
- biomass
- respiration
- chemical equation
- biological molecule
- compound
- flow of matter
- hydrocarbon
- hydrogen
- living system
- net transfer
- photosynthesizing organism
- carbon cycle
- solar energy
- efficient
- excitatory molecule
- molecular synthesis
- organic compound synthesis
- stomata
- transform matter and/or energy
- transport matter and/or energy

Phenomena

Some example phenomena for MS-LS1-6:

- A plant is kept in a clear, closed container that allows sunlight to pass through. After a week, the plant is dead. A mouse kept alone in the same container also dies. However, a plant and mouse kept together in the same container after one week are alive.
- The plant Elodea releases bubbles at an increased rate when an aquatic animal is added to the same aquarium.
- The aquatic plant Elodea grown in a solution of bromothymol blue will turn the solution from yellow to blue when grown in the light, and will remain in a yellow solution when grown in the dark.
- A plant grows in a pot of soil for one month. Only water is added to the pot. After one month, the plant has gained mass, while the mass of the soil has barely changed.
- A plant leaf kept in the light contains large amounts of starch, while a leaf kept in the dark does not.

Performance Expectation MS-LS1-7

Develop a model to describe how food is rearranged through chemical reactions to form new molecules that support growth and/or release energy as this matter moves through an organism.

Dimensions

Developing and Using Models

- Develop a model to describe unobservable mechanisms.

LS1.C: Organization for Matter and Energy Flow in Organisms

- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, support growth, or release energy.

PS3.D: Energy in Chemical Processes and Everyday Life

- Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on describing that molecules are broken apart and put back together and that energy is released in thus process.

Content Limits:

- Assessment does not include details of the chemical reactions for photosynthesis or respiration.
- Students do not need to know: enzymes, ATP synthase, metabolism, biochemical pathways, redox reactions, molecular transport, specific enzymes involved, catalysts.

Science Vocabulary Students Are Expected to Know

- molecules
- oxygen
- reaction
- cellular
- respiration
- energy
- carbon dioxide
- water
- sugar
- glucose
- ATP
- chemical bonds
- energy transfer
- photosynthesis
- proteins
- enzymes
- organelles
- nucleus
- DNA
- mitochondria
- cytosol
- cytoplasm
- nitrogen

Science Vocabulary Students Are Not Expected to Know

- biochemical
- fatty acids
- oxidizing agent
- electron acceptor
- biosynthesis
- locomotion
- phosphorylation
- electron transport chain
- chemiosmosis
- pyruvate
- pentose
- adenine
- phosphate
- amino acid
- fermentation
- aerobic respiration
- redox reactions
- oxidation
- reduction
- reducing agent
- oxidizing agent
- NAD+
- transport chain
- glycolysis
- citric acid cycle
- oxidative phosphorylation
- substrate-level phosphorylation
- acetyl COA
- cytochromes
- ATP synthase
- lactic acid
- transport matter and/or energy

Phenomena

Some example phenomena for MS-LS1-7:

- A young plant is grown in a bowl of sugar water. As it grows, the amount of sugar in the water decreases.
- A person feels tired and weak before they eat lunch. After they eat some fruit, they feel more energetic and awake.
- An athlete completing difficult training feels their muscles recover and repair faster when they eat more high-protein foods in a day compared to when they eat less protein in a day.
- Amoeba are provided food in a petri dish. When fed, the amoeba became more active and begin to grow and divide.
- Fungus grows on a damp piece of tree bark on the ground. When the tree bark is completely gone, the fungus stops growing and eventually dies.
- Mushrooms grow on a rotting tree stump. While the number of mushrooms increases, the tree stump slowly decays.

Performance Expectation MS-LS1-8

Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

Dimensions

Obtaining, Evaluating, and Communicating Information

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.

LS1.D: Information Processing

- Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural systems.

Clarifications and Content Limits

Content Limits:

- Assessment does not include mechanisms for the transmission of information from sensory receptors to the brain.
- Students do not need to know: Sensory transduction, ion channels, action potentials, sensory and motor cortices in the brain.

Science Vocabulary Students Are Expected to Know

- senses
- chemical
- mechanical
- memory
- perception
- process
- storage
- transfer
- transmit
- accuracy
- cell
- immediate
- nerve
- receptor
- sensory
- behavioral response to stimuli
- electromagnetic
- stimulus
- short-term memory
- long-term memory
- salt
- sour
- sweet
- bitter
- brain
- nervous system
- taste
- smell
- touch
- hear
- sight

Science Vocabulary Students Are Not Expected to Know

- neuron
- neurotransmitter
- endocrine signaling
- synapse
- axon
- olfactory
- rods
- cones
- trichromatic vision
- retina
- hair cells
- cochlea
- fight-or-flight response
- sensitization
- depolarization
- taste papillae
- umami

Phenomena

Some example phenomena for MS-LS1-8:

- A woman closes her eyes and touches the tip of her nose with her index finger
- A student is studying in a library. The fire alarm goes off and he involuntarily jumps out of his chair.
- A woman walking past a bakery smells cinnamon and is instantly reminded of her grandmother’s house.
- A driver sees a stoplight change from green to red and quickly moves his foot from the accelerator pedal to the break.

Performance Expectation MS-LS2-1

Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

Dimensions

Analyzing and Interpreting Data

- Analyze and interpret data to provide evidence of phenomena.

LS2.A: Interdependent Relationships in Ecosystems

- Organisms, and populations of organisms, are dependent on their environmental interactions, both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on cause and effect relationships between resources and growth of individual organisms, and the numbers of organisms in ecosystems during periods of abundant and scarce resources.
- Examples could include water, food, and living space.

Content Limits:

- Assessment does not include mathematical and/or computational representations of factors related to carrying capacity of ecosystems of different sizes (including deriving mathematical equations to make comparisons).

Science Vocabulary Students Are Expected to Know

- resource
- competition
- ecosystem
- nutrient
- food chain/web
- producer
- consumer

Science Vocabulary Students Are Not Expected to Know

- biotic component
- abiotic component
- exponential (AKA "logistic" growth
- ecological niche
- resource partitioning
- fundamental niche
- realized niche
- carrying capacity
- intraspecific competition
- interspecific competition

Phenomena

The phenomenon for these PEs are the given data. Samples of phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc.).

Some example phenomena for MS-LS2-1:

- On the north Atlantic coastline, two species of barnacles live at different depths.
- Cheetahs and leopards in the savannah use the same watering holes.
- After a drought period, the population of grasshoppers is halved.
- A garden is cleared of aphids. After a few days, the ladybirds in the surrounding trees are gone.

Performance Expectation MS-LS2-2
Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

Dimensions
Constructing Explanations and Designing Solutions
- Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.

LS2.A: Interdependent Relationships in Ecosystems
- Similarity, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving are shared.

Patterns
- Patterns can be used to identify cause and effect relationships.

Clarifications and Content Limits
Clarification Statements:
- Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of their relationships among and between living organisms and nonliving components of ecosystems.
- Examples of types of interactions could include competitive, predatory, and mutually beneficial.

Content Limits:
- Analysis may include recognizing patterns in data, specifying and explaining relationships, making logical predictions from data, retrieving information from a table, graph or figure and using it to explain relationships, generating hypotheses based on observations or data, and generalizing a pattern.
- Analysis should not include relating mathematical or scientific concepts to other content areas.

Science Vocabulary Students Are Expected to Know
- relative
- disperse
- ecological role
- host
- infection
- mutualism
- mutually beneficial
- parasite
- evolve
- genetic
- interdependent

Science Vocabulary Students Are Not Expected to Know
- abiotic

Phenomena

For this performance expectation, the phenomena are sets of data. Those are the observed facts that the students will look at to discover patterns. Below, we enumerate some of the patterns that might comprise the data sets (phenomena) to be analyzed

Some example phenomena for MS-LS2-2:

- The tongue of the alligator snapping turtle looks like a small worm. The turtle uses this tongue to lure prey close to its mouth. (Predation)- also angler fish.
- Higher density of squirrels in oak environment than in maple environment.
- Hippopotamuses spend time in both aquatic and savannah ecosystems. When found in aquatic environments, they're often surrounded by carp. When found in a savannah environment, they are often surrounded by oxpeckers.
- In Ecuador's Andean Cloud Forest, a hummingbird feeds on the nectar of an orchid flower (Epindendrum secundum). In Madagascar, a similar orchid flower (Angraecum sequipedale) is seen, but no hummingbirds are found.

Performance Expectation MS-LS2-3

Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Dimensions

Developing and Using Models

- Develop a model to describe phenomena.

LS2.B: Cycle of Matter and Energy Transfer in Ecosystems

- Food webs are models that demonstrate how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

Energy and Matter

- The transfer of energy can be tracked as energy flows through a natural system.

Clarifications and Content Limits

Clarification Statements:

- Emphasize food webs and the role of producers, consumers, and decomposers in various ecosystems.
- Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.

Content Limits:

- Assessment does not include the use of chemical reactions to describe the processes.
- Assessment does not include identification of trophic levels, understanding of the relative energies of the trophic levels, nor the knowledge of the 10% energy transfer between trophic levels.
- Assessment does not include the concept of biomass.
- Assessment does not include the process of bioaccumulation.
- Students do not need to identify biomes or to know information about specific biomes.

Science Vocabulary Students Are Expected to Know

- food web
- food chain
- producer
- consumer
- decomposer
- herbivore
- omnivore
- carnivore
- algae
- fungi
- microbe
- microorganism
- organic matter/waste
- nutrients
- photosynthesis
- atom
- molecule
- sugar
- carbon
- carbon Dioxide
- nitrogen
- oxygen
- Law of conservation of matter
- Law of conservation of energy
- predator
- prey
- atmosphere
- aquatic
- interdependent

Science Vocabulary Students Are Not Expected to Know

- biotic
- abiotic
- trophic level
- energy pyramid
- nitrogen fixation
- exothermic/endothermic
- detritivores
- biomass
- bioaccumulation/biomagnification
- autotroph/heterotroph
- biosphere
- hydrosphere
- geosphere
- aerobic
- anaerobic
- chemical reaction
- reactant
- product
- phosphorous
- phytoplankton

Phenomena

Some example phenomena for MS-LS2-3

- In the Alaskan tundra, more grass and wildflowers grow on top of underground fox dens than elsewhere.
- In July, a colony of lava crickets is found to inhabit lava flows from a May eruption, but the first plant does not appear in the area until November.
- Fox-inhabited islands in the Aleutian Islands have less vegetation than islands not inhabited by foxes.
- Giant clams and tube worms are found in the darkest parts of the oceans in the hot water near hydrothermal vents.

Performance Expectation MS-LS2-4

Construct an argument supported by evidence that the stability of populations is affected by changes to an ecosystem.

Dimensions

Engaging in Argument from Evidence

- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Ecosystems are dynamic in nature: their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Stability and Change

- Small changes in one part of a system might cause large changes in another part.

Clarifications and Content Limits

Clarification Statements:

- Emphasize how changes to living and nonliving components in an ecosystem affect populations in that ecosystem.
- Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.
- Examples could include Utah ecosystems such as mountains, Great Salt Lake, wetlands, and deserts.

Content Limits:

- Assessment does not include the use of chemical reactions to describe the processes.

Science Vocabulary Students Are Expected to Know

- predator
- mutually beneficial interactions
- competition
- food web
- consumers
- producers
- decomposers
- biodiversity

Science Vocabulary Students Are Not Expected to Know

- anthropogenic changes
- carrying capacities

Phenomena

Some example phenomena for MS-LS2-4:

- After a beaver builds a dam, the amount and diversity of fish life in a stream increases.
- After wolves were reintroduced to Yellowstone, there were more willows.
- The number of willows has increased in Yellowstone. (Give two competing hypotheses: wolf introduction; beaver population increase).
- As the Aral Sea declined in size since the 1960s, salinity has increased and the Aral trout is no longer present in the lake.
- The area of the Gulf of Mexico around the Mississippi Delta has large algal blooms.

Performance Expectation MS-LS2-5

Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Dimensions

Engaging in Argument from Evidence

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystems' biodiversity is often used as a measure of its health.

LS4.D: Biodiversity and Humans

- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on-for example, fresh air and water (secondary).

ETS1.B: Ecosystem Dynamics, Functioning, and Resilience

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (secondary).

Stability and Change

- Small changes in one part of a system may cause a large change in another.

Clarifications and Content Limits

Clarification Statements:

- Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion.
- Examples of design solution constraints could include scientific, economic, and social considerations.

Content Limits:

- Students do not need to know: specific policies or specific details of organisms.

Science Vocabulary Students Are Expected to Know

- habitats
- ecosystem
- niche
- native species
- non-native or invasive species
- biodiversity
- resources

Science Vocabulary Students Are Not Expected to Know

- specific species names
- specific resource or habitat requirements for any species

Phenomena

Engineering PE's are built around meaningful design problems rather than phenomena. In this case, the design problems involve preserving ecosystems and protecting biodiversity. For this PE, the design problem and competing solutions replace phenomena.

Some example design problems for MS-LS2-5:

- Giant African Land Snails were brought to Florida by a boy who smuggled three snails into Florida. His grandmother released these into a garden and the snail population exploded. The snails eat over 500 plant species, tree bark, paint, and even stucco. Florida has implemented four solutions:
    - Trained dogs that sniff out snails for capture.
    - Chemicals applied to plants that the snails feed upon.
    - Predatory species to eat the snails.
- The brown tree snake was accidentally brought to the island of Guam by ships during World War II, fed on native birds until the Guam rail, a native bird, nearly went extinct in 1984. Guam has implemented two solutions:
    - Feed rats acetaminophen and drop them into wooded areas.
    - Bring in predatory species to eat the snakes.
- Cheatgrass, a type of weed that was brought to the United States in the late 1800s, has spread all over Utah from the desert valleys to the mountains, growing faster than most native plants. Utah has implemented two solutions:
    - Use genetically modified seeds for certain native seeds that are heartier than the Cheatgrass to push out the Cheatgrass seeds.
    - Controlled application of herbicides.
- Asian carp is an aggressive fish species introduced in 1960 to control weed populations in waterways in southern fish farm ponds. The population was sterilized but a few fertile fish escaped into the Mississippi River and migrated north towards the Great Lakes. Asian carp are an invasive species that compete with native fish in the Great Lakes and threaten the ecosystem balance. Regions around the Great Lakes are implementing strategies:
    - Launch a campaign to encourage and incentivize fishing of Asian carp for human consumption
    - Use a system of electric barriers to prevent Asian carp form entering Lake Michigan form the Mississippi River.
    - Use nets to block to popular spawning sites during Asian carp reproduction season
    - Introduce a botanic pesticide used for fish eradications in water areas known to have large Asian carp populations.

Performance Expectation MS-LS3-1

Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of an organism.

Dimensions

Developing and Using Models

- Develop and use a model to describe phenomena.

LS3.A: Inheritance of Traits

- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.

LS3.B: Variation of Traits

- In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among their parts; therefore, complex natural structures/ systems can be analyzed to determine how they function.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.

Content Limits:

- Assessment does not include specific changes of genes at the molecular level, mechanisms for protein synthesis, and specific types of mutations.
- Do not use examples of mutations in humans.
- Analysis does not include species-level sources of genetic variation, including the founder effect, bottleneck, genetic drift, or Hardy-Weinberg equilibrium.

Science Vocabulary Students Are Expected to Know

- gene
- genome
- genotype
- phenotype
- DNA
- mutation
- pedigree
- parent generation
- trait
- beneficial
- positive
- harmful
- negative
- neutral
- environment
- pollination

Science Vocabulary Students Are Not Expected to Know

- RNA
- transcription
- translation
- mitosis
- meiosis
- interphase
- prophase
- metaphase
- anaphase
- telophase
- cytokinesis
- zygote
- fertilization
- dominant
- recessive
- codominance
- incomplete dominance
- allele
- Punnett square
- Sequencing
- F1
- F2
- Haploid
- Diploid
- epigenetics
- plasmid

Phenomena

Some example phenomena for MS-LS3-1:

- Use of antibiotics in farming has leeched antibiotics into the water system. However, resistant bacteria persist in groundwater and are difficult to kill.
- Every year, the flu vaccine is different, depending on the most prevalent strain of flu virus.
- Wild almond trees produce the poisonous chemical amygdalin. Occasional individual almond trees have a mutation that cause them to not produce amygdalin. These individual plants are cultivated on almond farms.
- A farmer observed on corn plant producing corn cobs with larger kernels. The farmer planted seeds from that plant and the offspring corn plants also had larger kernels.
- Thale cress plants sprout in the spring and flower about a month later.

Performance Expectation MS-LS3-2

Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

Dimensions

Developing and Using Models

- Develop and use a model to describe phenomena.

LS1.B: Growth and Development of Organisms

- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring (secondary).

LS3.A: Inheritance of Traits

- Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.

LS3.B: Variation of Traits

- In sexually reproducing organisms, each parent contributes (at random) half of the genes acquired by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural systems.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on using models such as Punnett Squares, diagrams and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.

Content Limits:

- Assessment does not include phases of mitosis or meiosis.
- Students do not need to know process of recombination.

Science Vocabulary Students Are Expected to Know

- breed
- transfer
- development
- germination
- plant structure
- plumage
- reproductive system
- fertilizer
- gene
- genetic
- variation
- allele
- dominant trait
- recessive trait
- hereditary information
- Punnett square
- transmission
- chromosome
- sexual reproduction
- asexual reproduction
- protein

Science Vocabulary Students Are Not Expected to Know

- DNA
- DNA replication
- sex-linked trait
- recombination
- gene expression
- segment
- sex cell
- sex chromosome
- cell division
- mutation
- meiosis
- amino acid
- amino acid sequence
- haploid
- diploid

Phenomena

Some example phenomena for MS-LS3-2:

- Jellyfish will produce both clones and genetically diverse offspring during different stages of their life cycle.
- Strawberry plants grow another stem from a core stem that extends horizontally on the ground. This new stem will become a separate strawberry plant.
- A flatworm is cut in half. Rather than dying, both halves regenerate their lost portions to form two new, distinct, and fully functioning worms.
- A plant (Bryophyllum diagremontianum) native to Madagascar has what appears to be miniature clusters of leaves lining the edges of a much larger leaf.

Performance Expectation MS-LS4-1

Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change life forms throughout the history of life on Earth, under the assumption that natural laws operate today as in the past.

Dimensions

Analyzing and Interpreting Data

- Analyze and interpret data to determine similarities and differences in findings.

LS4.A: Evidence of Common Ancestry and Diversity

- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.

Patterns

- Graphics, charts, and images can be used to identify patterns in data.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.

Content Limits:

- Does not include: genetic analysis, comparisons of fossils to extant organisms, embryological evidence, genetic variation, inheritance, selective pressures.
- Students do not need to know: the names of individual species/genera or intervals of geological time, taxonomy, processes of fossil information.

Science Vocabulary Students Are Expected to Know

- organism
- fossil
- diversity
- extinction
- structure
- sedimentary rock
- volcanic rock
- radioactive dating
- mineral
- extinct
- unicellular
- multicellular
- organelles
- nucleus
- ancestor
- ancestry
- species
- evolve
- anatomical

Science Vocabulary Students Are Not Expected to Know

- cladogram
- phylogenetics
- phylogenetic
- systematics
- phylum
- phyla
- class
- order
- family
- genus
- genera
- homologous
- analogous
- divergent
- convergent
- prokaryote
- eukaryote

Phenomena

For this performance expectation the phenomena are sets of data. Those are the observed facts that the kids will look at to discover patterns. Below, we enumerate some of the patterns that might comprise the data sets (phenomena) to be analyzed.

Stimuli might commonly include one or more geological column, data on what fossils are found in that (those) column(s), and the characteristics of those fossils. When more than one column is to be used in the analysis, sufficient data re given to anchor the ages of one or more key strata. Students would set out to identify and articulate patterns in the data.

Some example phenomena for MS-LS4-1:

- Prior to 542 million years ago, the fossil record shows relatively simple organisms without much variation. Layers in the fossil record between 542 million years ago to 476 million years ago shows the Cambrian Explosion- a time of significant evolution of animals, beginning with trilobites and ending with vertebrate fish. The Cambrian Explosion closed with a major extinction.
- 525-year-old rock layers contain the earliest vertebrate fossils, which are of fish. These fossil fish had a cartilage skull with no jaw, and lacked a vertebral column. Fossils in 450 million-year-old rocks include vertebrate fish with a cartilage jaw and vertebral column. Four hundred-year-old rocks include fish with skills that include jaws and vertebrates made of bone.

Performance Expectation MS-LS4-2

Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

Dimensions

Constructing Explanations and Designing Solutions

- Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events.

LS4.A: Evidence of Common Ancestry and Diversity

- Anatomical similarities and differences among organisms living today, and between contemporary organisms and those in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent.

Patterns

- Patterns can be used to identify cause and effect relationships.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on explanation of the relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.
- Emphasis is on using anatomical similarities and differences to infer relationships among different modern organisms.
- Emphasis is on understanding that the changes over time in the anatomical features seen in fossil records can be used to infer relationships between extinct organisms to living organisms.
- Emphasis is on understanding that organisms that share a pattern of anatomical features are likely to be more closely related than are organisms that do not share a pattern of anatomical features

Content Limits:

- Students do not need to know: name of specific fossil species; knowledge of specific fossils or anatomical features; genetic variation, process of fossil formation, knowledge of geologic time periods; knowledge of rock layer; relationship between fossils and age of rock layers; molecular homology (similarities in DNA, RNA, and protein sequence).

Science Vocabulary Students Are Expected to Know

- homologous
- analogous
- organism
- fossil
- diversity
- extinction
- structure
- radioactive dating
- mineral
- extinct
- unicellular
- multicellular
- organelles
- ancestor
- ancestry
- species
- evolve
- anatomical

Science Vocabulary Students Are Not Expected to Know

- cladogram
- phylogenetic tree
- dichotomous tree
- phylum/phyla
- class
- order
- family
- genus/genera
- divergent
- convergent
- prokaryote
- eukaryote
- types of rock (sedimentary, igneous, metamorphic)
- embryology

Phenomena

Some example phenomena for MS-LS4-2:

- Bats and frogs have forelimbs that look very different, but have similar bones and overall structure.
- Comparing the skull bones of the modern-day whale to the fossilized skulls of Dorudon and Pakicetus, shows a pattern in the position of the nostril as these organisms changed over millions of years.
- Wings are structures that allow most birds to fly, except penguins, which have wings but cannot fly. Modern-day whales live in the ocean but have small hind-legs.

Performance Expectation MS-LS4-3

Analyze displays of pictorial data to compare patterns of similarities in embryological development across multiple species to identify relationships not evident in the fully formed anatomy.

Dimensions

Analyzing and Interpreting Data

- Analyze displays of data to identify linear and nonlinear relationships.

LS4.A: Evidence of Common Ancestry and Diversity

- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully formed anatomy.

Patterns

- Graphs, charts, and images can be used to identify patterns in data.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic of diagrams or pictures.

Content Limits:

- Assessment of comparisons is limited to observable (with the naked eye) appearances of anatomical structures in embryological development.

Science Vocabulary Students Are Expected to Know

- embryo
- embryology
- development
- anatomy
- organisms
- relatedness
- species
- mammal
- reproduce
- mitosis
- meiosis
- body structure
- limb
- fetus
- organ
- tissues
- cell

Science Vocabulary Students Are Not Expected to Know

- placenta
- homologous structures
- external fertilization
- internal fertilization
- zygote
- differentiation
- gamete
- blastula
- mesoderm
- endoderm
- ectoderm
- notochord

Phenomena

For this performance expectation, the data will consist of pictures, diagrams, etc. Students will be challenged to find patterns and similarities.

Some example phenomena for MS-LS4-3:

- Early mammal embryos and early fish embryos both contain gill slits. In fish embryos, these gill slits develop into gills. In human embryos, the gill slit disappear before birth.
- The embryos of chicks, humans, and koalas have tails, and muscles to move the tails. However, as the embryos develop, the tails disappear.
- The limb buds of early bird embryos are very similar to the limb buds of early human embryos. The limb buds of the bird embryos become wings, while the limb buds of human embryos become arms.
- The early embryos of fish, birds, rabbits, and humans all have two-chambered hearts.
- Early baleen whale embryos have tooth buds and a coat of hair. During development, the tooth buds are resorbed before birth and never exit through the gums. The coat of hair also disappears before birth.
- Early stage embryos of many animal species have backbones so similar that they can be hard to tell apart until later in their development.

Performance Expectation MS-LS4-4

Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

Dimensions

Constructing Explanations and Designing Solutions

- Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena.

LS4.B: Natural Selection

- Natural selection leads to the predominance of certain traits in a population, and the suppression of others.

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on using simple probability statements and proportional reasoning to construct explanations.
- Emphasize the use of proportional reasoning to support explanations of trends in changes to populations over time.
- Examples could include camouflage, variation of body shape, speed and agility, or drought tolerance.

Content Limits:

- Students do not need to know: dominant/recessive traits, modes of inheritance (polygenic, sex-linked, etc.)

Science Vocabulary Students Are Expected to Know

- diversity
- trend
- predation
- abundance
- evolve
- evolution
- gene
- genetic variation
- allele
- sexual reproduction
- beneficial
- probability
- distribution
- adaptation
- adaptive characteristics
- frequency
- natural selection
- population

Science Vocabulary Students Are Not Expected to Know

- DNA
- dominant traits
- recessive traits
- gene expression
- polygenic traits
- sex-linked traits
- mutation
- advantageous
- heritable
- cline
- microevolution
- gene pool
- genetic drift
- founder effect
- bottleneck effect
- gene flow
- relative fitness

Phenomena

Some example phenomena for MS-LS4-4:

- The orchid mantis attracts pollinators of the orchid as prey.
- In New Mexico, the rock pocket mice found in dark, rocky areas of the Valley of Fire all have dark fur.
- Male frigate birds with larger red pouches are more likely to find a mate.
- Some *Staphylococus areus* bacteria are able to survive following treatment with the antibiotic methicillin.
- The diamondback moth is a pest of many crops. When a field is sprayed with pesticides targeting the moth, some diamondback moths can survive.

Performance Expectation MS-LS4-5

Gather and synthesize information about technologies that have changed the way humans influence the inheritance of desired traits in organisms.

Dimensions

Obtaining, Evaluating, and Communicating

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and method used, and describe how they are supported or not supported by evidence.

LS4.B: Natural Selection

- In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, and gene therapy) and on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.

Content Limits:

- Students do not need to know: overlapping DNA sequences, Hardy-Weinberg calculations, biodiversity, mechanisms of gene transfer, dominant/recessive genes.

Science Vocabulary Students Are Expected to Know

- natural / artificial selection
- evolution adaptation
- resources reproduction
- offspring breeding Traits
- organisms Genetic engineering
- DNA, cloning
- inherit
- hereditary
- proteins

Science Vocabulary Students Are Not Expected to Know

- chromosomes
- genetic variation
- genetic combination
- meiosis
- mitosis
- replications
- mutations
- gene regulation
- allele
- DNA sequences
- RNA sequences
- amino acid sequences

Phenomena

Some example phenomena for MS-LS4-5:

- Different methods for transferring genes have different rates of success:
- Scientists insert the pGLO plasmid into plants so that the plants glow when they are ready to harvest.
- There is no wild plant that looks like modern corn (soft starchy kernels lined up in a row).
- Farmers isolated wild cabbage plants to create a variety of vegetables, including broccoli and kale. The wild cabbage plants were selected for their different flavors, textures, leaves, and flowers.
- Scientists are currently working to breed sheep that do not burp in order to reduce methane emission.
- Scientists want to breed strong and more resistant bees that won't be damaged by disease and other parasites.
- Scientists have created pest-resistant cotton that is toxic to certain insects that eat the plant.
- Scientists are working to produce drought-resistant sugarcane for farming in dry areas.
- Scientists are working to create animals that have a smaller environmental impact (Enviro-Pig).
- Scientists are working to create plants with immunities to plant diseases.
- Scientists are creating bacteria that produce some specialized substances (insulin, other proteins, medicines).
- Scientists are making animal models of human diseases for study.

Performance Expectation MS-LS4-6

Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Dimensions

Using Mathematics and Computational Thinking

- Use mathematical representations to support scientific conclusions and design solutions.

LS4.C: Adaptation

- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.

Content Limits:

- Math can include measures of central tendency, basic operations that can be calculated without a calculator, and basic graphical analysis (bar chart, pie chart, scatter plot, box and whisker plot, line chart, etc.).
- Students aren’t expected to know the mechanisms of genetic inheritance or mutation.
- Assessment does not include Hardy-Weinberg calculations.
- Assessment does not include other mechanisms of evolution (genetic drift, co-evolution, gene flow, etc.)

Science Vocabulary Students Are Expected to Know

- adapt
- adaptation
- climate
- environment
- evolution
- trait
- inherit
- generation
- species
- genus
- reproduction
- distribution
- ratio

Science Vocabulary Students Are Not Expected to Know

- morphology
- genetic variance
- embryology
- proliferation
- biotic
- abiotic

Phenomena

Some example phenomena for MS-LS4-6:

- Some bacteria are killed by a certain antibiotic while other bacteria are immune to it. After the antibiotic is used once, bacteria die. The next time the antibiotic is used, there are many bacteria left.
- The Sandhills in Nebraska used to be covered in dark-colored soli. Most deer mice living in this area hard dark-colored fur coats, while others had light-colored fur coats. Over time, the Sandhills were covered in light-colored sand. After many. Years, the population of deer mice had mostly light-colored fur coats. This will be presented as data.
- In the Galapagos Islands, there are finches with thin, small beaks that eat small, soft seeds. These also finches with thick, large beaks that eat larger hard and dry seeds. A drought period in 1977 affected the plant life on the islands, greatly reducing the number of small, soft seeds. The next year, there were far more large-beaked birds than small-beaked birds.

Performance Expectation MS-PS1-1

Develop models to describe the atomic composition of simple molecules and extended structures.

Dimensions

Developing and Using Models

- Develop and/or use a model to predict and/or describe phenomena.

PS1.A: Structure and Properties of Matter

- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales, using models to study systems that are too large or too small.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on identifying elements vs. compounds and their basic units of atoms and molecules.
- Emphasis is on developing models of molecules that vary in complexity.
- Examples of simple molecules could include ammonia, methanol, methane, water, carbon dioxide, etc.
- Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.

Content Limits:

- Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.
- Modelling should be limited to molecules that have only one type of bond, no combination of bonds; the structure of the molecule is easy to model; single bonded molecules.
- Examples of extended structures could include sodium chloride or diamonds.
- Students are not expected to memorize the atomic characteristics of any element.
- Students do not need to know: valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, a complete description of all individual atoms in a complex molecule or extended structure, memorization of atoms found in different molecule, VSEPR or geometric arrangements, the difference between single, double, and triple bonding, periodic table patterns and how it affects bonding, oxidation numbers, polyatomic ions.

Science Vocabulary Students Are Expected to Know

- atoms
- molecules
- element
- compound
- mixtures
- homogenous
- heterogeneous
- pure substances
- solution
- solvent
- solute

Science Vocabulary Students Are Not Expected to Know

- valence electrons
- subatomic particles such as protons
- electrons
- neutrons
- neutrinos etc.
- ions
- positive or negative charges
- covalent bond
- ionic bond

Phenomena

Some example phenomena for MS-PS1-1:

- Submarines can stay underwater for months using sea water as a source of oxygen for air. Special machines run electricity through large amounts of sea water, generating oxygen from the water.
- Water and hydrogen peroxide are both made up of hydrogen and oxygen. When water is poured on a chunk of $CaCO_3$, there is no reaction. When hydrogen peroxide is poured on a chunk of $CaCO_3$, it fizzes.
- Graphite is an extremely soft substance and diamonds are the hardest substance known. Both are made completely of carbon atoms in different arrangements.
- Oxygen (O_2) is a gas we breathe to stay alive. Ozone (O_3), also made only of oxygen atoms, is unhealthy to breathe.

Performance Expectation MS-PS1-2

Analyze and interpret data on the properties of substances before and after the substances interact to determine whether a chemical reaction has occurred.

Dimensions

Analyzing and Interpreting Data

- Analyze and interpret data to determine similarities and differences in findings.

PS1.A: Structure and Properties of Matter

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

Clarifications and Content Limits

Clarification Statements:

- Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.

Content Limits:

- Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.
- Students are not expected to balance chemical equations or to determine whether a chemical equation is balanced or not.
- Students are expected to know that mass/matter is neither destroyed nor created.

Science Vocabulary Students Are Expected to Know

- reactant
- product
- atom
- molecule
- compound
- matter
- chemical property
- physical property
- mass
- volume
- density
- melting point
- boiling point
- freezing point
- solubility
- dissolve
- flammability
- odor
- gas
- solid
- liquid
- chemical bonds

Science Vocabulary Students Are Not Expected to Know

- conservation of energy
- collision theory
- oxidation
- reduction
- intramolecular attractions
- intermolecular attractions
- solvent
- solute
- precipitant
- limiting reactant
- excess reactant
- covalent bond
- ionic bond
- rate of chemical reaction
- acid
- base
- salt (as an ionic crystal)
- law of conservation of mass
- fusion
- fission
- homogenous mixture
- heterogeneous mixture

Phenomena

For this performance expectation the phenomena are mixtures of substances that provide sets of data. Those are the observations and/or measurements concerning the physical and chemical properties of the involved substances before and after mixing that the kids will look at to discover patterns. Below, we enumerate some of the mixtures that might provide the data sets to be analyzed.

All phenomenon for this PE should be situations where a chemical reaction is not immediately apparent.

Some example phenomena for MS-PS1-2:

- Rainwater can produce stains on car paint. Reports of these stains are more common in the Southeastern U.S. than they are in the Midwest.
- Steel corrodes when exposed to rainwater. Aluminum exposed to rainwater does not.
- Portions of marble statues that are exposed to rainwater crack and crumble over time. Portions of marble statues that are sheltered develop a black coating over time.
- When sugar crystals are added to vinegar in a bowl, the crystals disappear. When crystals of table salt are added to vinegar in a bowl, the mixture begins to bubble and foam.
- Table sugar exposed to an open flame transforms into a gooey, dark substance. Wood exposed to an open flame transforms into ash

Performance Expectation MS-PS1-3

Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

Dimensions

Obtaining, Evaluating, and Communicating Information

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.

PS1.A: Structure and Properties of Matter

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on natural resources that undergo a chemical process to form the synthetic material.
- Examples of new materials could include new medicine, foods, building materials, plastics and alternative fuels.

Content Limits:

- Students are not required to know particular names for synthetic materials (i.e., rayon, polyester, acrylic, nylon, rayon, acetate, Orion, Kevlar).
- Students do not need to know the types of reaction mechanisms involved in chemical reactions such as polymerization.

Science Vocabulary Students Are Expected to Know

- atom
- molecule
- building block
- pure substance
- subunit
- molecular arrangement
- matter
- particle
- pressure
- conductivity
- reactant
- dissolve
- mineral
- conductive
- properties of elements
- chemical properties
- separation method (for mixtures)
- sodium chloride
- negative impact
- petroleum
- natural gas
- oil

Science Vocabulary Students Are Not Expected to Know

- acid
- base
- reversible reactions
- irreversible reactions
- condensation reaction
- polymer
- polymerization
- bond
- electron configuration
- chromatography
- catalyst
- bulk scale
- electron transfer
- graphite
- pharmaceutical
- synthetic polymer
- harvesting of resources
- oil shale
- geopolitical
- extract
- cost-benefit
- organic chemicals
- organic materials

Phenomena

Some example phenomena for MS-PS1-3:

- Naturally occurring penicillin from penicillium mold is an effective antibiotic against infections, but it is broken up by stomach acid and can only be injected into the bloodstream.
- The bark of the white willow tree can be used as an alternative to aspirin for pain relief.
- Nylon and Kevlar are both synthetic fabrics, but Kevlar is much stronger: about five times as strong as steel.
- PVC is stronger, cheaper, more lightweight and more durable than traditional building materials like wood, metal, or concrete.
- Aspartame and sucralose are hundreds of times sweeter than naturally occurring sugars.
- Taxol was originally an expensive cancer drug because it is difficult to extract from the bark of the Pacific yew tree.
- While vanilla flavor is in high demand, natural methods for extracting it are challenging and costly.

Performance Expectation MS-PS1-4

Develop a model that predicts and describes change in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

Dimensions

Developing and Using Models

- Develop a model to predict and/or describe phenomena.

PS1.A: Structure and Properties of Matter

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other.
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations.
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

PS3.A: Definitions of Energy

- The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. (secondary)
- The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system's material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material (secondary).

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs.
- Examples of models could include drawings and diagrams.
- Examples of particles could include molecules and inert atoms.
- Examples of pure substances could include water, carbon dioxide, and helium.

Content Limits:

- Ideal gas laws and their relationships (Boyle's, Charles, Combined, PV=nRT, etc.);
- Physical changes that only entail states of matter consisting of sold, liquid, and gas (not plasma) and also do not entail sublimation (solid change of state directly to a gas);
- Calculations for internal energy, transfer of heat (q), (system and surroundings), entropy, work, and Hess's law;
- The role that pressure and force (N) have in the kinetic molecular theory;
- Energy needed to break and reform chemical bonds in a chemical reaction, including the use of a catalyst to speed up a reaction;
- Absolute zero and kelvin temperature units should not be included (Celsius and Fahrenheit units only)
- Students do not need previous knowledge of:
    - Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
    - The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
    - Stable forms of matter are those in which the electric and magnetic field energy is minimized.

- A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to break the bonds of a molecule.
- That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and among its various possible forms.

Science Vocabulary Students Are Expected to Know

- particle motion
- temperature
- state
- change of state
- phase
- phase change
- thermal energy
- atom
- molecule
- solid
- liquid
- gas
- kinetic energy
- pure substance
- compound
- thermometer
- matter
- melting
- freezing
- condensation
- vapor
- heat
- vibrate
- collide
- inert atom

Science Vocabulary Students Are Not Expected to Know

- entropy
- enthalpy
- ideal gas law
- sublimation
- plasma
- triple point
- critical point
- proton
- neutron
- electron
- valence electrons
- electrical energy
- bond energy

Phenomena

Some example design projects for MS-PS1-4:

- A tea kettle is sitting on a stove, under heat. As the water in the kettle begins to boil, a stream of steam is visible outside of its spout.
- Dew forms on the grass in the morning.
- As sugar is heated in a pan, it turns from a white solid to a light brown liquid.

Performance Expectation MS-PS1-5

Develop a model to describe how the total number of atoms does not change in a chemical reaction, indicating that matter is conserved.

Dimensions

Developing and Using Models

- Develop and use a model to describe unobservable mechanisms.

PS1.B: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.
- The total number of each type of atom is conserved and thus the mass does not change.

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes.

Clarifications and Content Limits

Clarification Statements:

- Emphasize demonstrations of an understanding of the law of conservation of matter.
- Emphasis is on law of conservation of matter and on physical models or drawings, including digital formats that represent atoms.
- Models can include already balanced chemical equations.

Content Limits:

- Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.
- Assessment does not include stoichiometry or balancing equations.
- Assessment is limited to simpler molecules, i.e., carbon dioxide, ammonia, sodium chloride, methanol, calcium chloride

Science Vocabulary Students Are Expected to Know

- transfer
- molecule
- element
- conversion
- phase change
- dissolve
- reactant
- product

Science Vocabulary Students Are Not Expected to Know

- acid-base reactions
- base
- catalyst
- reaction rate
- endothermic
- exothermic
- equilibrium
- oxidation-reduction reaction
- chemical bond
- electron sharing
- electron transfer
- ion
- isotope

Phenomena

Some example design projects for MS-PS1-5:

-

Performance Expectation MS-PS1-6

Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

Dimensions

Constructing Explanation and Designing Solutions

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

PS1.B: Chemical Reactions

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (secondary)

ETS1.C: Optimizing the Design Solution

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process-that is, some characteristics may be incorporated into the new design. (secondary)
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (secondary)

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance.
- Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride

Content Limits:

- Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.
- Students do not need to know.
    - Types of chemical reactions (decomposition, synthesis, single replacement, double replacement, combustion, etc.)
    - How to balance a chemical equation

Science Vocabulary Students Are Expected to Know

- chemical change
- chemical reaction
- reactant
- product
- chemical bond
- compound
- molecule
- solution
- dissolve
- soluble/solubility
- concentration
- chemical potential energy
- thermal energy
- system
- environment
- evaporate
- condense

Science Vocabulary Students Are Not Expected to Know

- endothermic
- exothermic
- precipitant
- solute
- solvent
- crystallization
- dissolution
- polar/polarity
- ion
- intermolecular force
- intramolecular force
- enthalpy
- entropy
- heat of solution
- heat of reaction
- microstates
- equilibrium
- saturate/saturation

Phenomena

Some example design projects for MS-PS1-6:

- Design a sport’s injury pack that when used, will heat and soothe sore muscles.
- Design a sport’s injury cold pack that will help prevent swelling.
- Design a self-heating pad that can warm ready-to-eat meal.
- Design a device that can be used to keep electronics like computers from overheating.

Performance Expectation MS-PS2-1

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic level.

Dimensions

Analyzing and Interpreting Data

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic things.

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Clarifications and Content Limits

Clarification Statements:

- Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.

Content Limits:

- Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.
- Stating the law or naming the law is not part of this PE.

Science Vocabulary Students Are Expected to Know Attraction

- velocity
- acceleration
- net force
- friction
- air resistance
- impulse
- vectors
- slope
- y-intercept

Science Vocabulary Students Are Not Expected to Know

- terminal velocity

Phenomena

The phenomenon for these PEs are the given data. Samples of phenomena should describe the data set(s) to be given in terms of patterns or relationships to be found in the data, and the columns and rows of a hypothetical table presenting the data, even if the presentation is not tabular. The description of the phenomenon should describe the presentation format of the data (e.g., maps, tables, graphs, etc.).

Some example phenomena for MS-PS2-1:

- Force is removed from two vehicles' accelerator pedals. The vehicles' positions over time are given.
- A water tank railcar is pulled by a train engine at constant speed and develops a leak allowing water to escape. The position and velocities of the water tank and train over time are given.
- A heavy model rocket rises a shorter distance than a lighter model rocket using the same type of engine. The position of each rocket over time is given.
- A falling skydiver's velocity increases for several minutes and then reaches a maximum speed. The velocity of the skydiver over time is given.

Performance Expectation MS-PS2-2

Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Dimensions

Planning and Carrying Out Investigations

- Plan an investigation individually and collaboratively, and in the design; identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data re needed to support a claim.

PS2.A: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on:
  - Balanced (Newton's First Law) and unbalanced forces in a system.
  - Qualitative comparisons of forces, masses and changes in motion (Newton's Second Law)
  - Frame of reference and specification of units

Content Limits:

- Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time.
- Students do not need to know: trigonometry

Science Vocabulary Students Are Expected to Know Attraction

- pull
- push
- change of motion
- applied force
- balanced force
- collision
- force
- unbalanced force
- position over time
- control
- independent variable
- dependent variable
- mass
- net force

Science Vocabulary Students Are Not Expected to Know

- Newton's Laws of Motion
- acceleration
- velocity
- inertial frame of reference
- momentum
- friction

Phenomena

Some example phenomena for MS-PS2-2:

- A tennis ball is dropped on a trampoline and bounces up to a height, h. A bowling ball is then dropped on the same trampoline. The bowling ball bounces up to a height higher than h.
- A bowling ball is rolled towards a bowling pin. When the bowling ball hits the pin, the pin falls down. Then, a marble is rolled towards a bowling pin. When the marble hits the pin, the pin does not fall down.
- A soccer player kicks the ball 50 yards. She then kicks another ball and it only goes 30 yards.
- Two magnets of the same size are held apart from each other. One magnet is let go and moves towards the stationary magnet. When two other magnets are close to each other and one is let go, it moves toward the stationary magnet, faster.

Performance Expectation MS-PS2-3

Ask questions about data to determine the factors that affect the strength of electrical and magnetic forces.

Dimensions

Asking Questions and Defining Problems

- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.

PS2.B: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Clarifications and Content Limits

Clarification Statements:

- Examples could include electromagnets, electric motors, or generators.
- Examples of data could include the effect of the number or turns of wire on the strength of an electromagnet, or of increasing the number or strength of magnets on the speed of an electric motor.

Content Limits:

- Quantitative responses are limited to proportional reasoning and algebraic thinking.

Science Vocabulary Students Are Expected to Know Attraction

- charge
- conductor
- electric charge
- electric current
- electric field
- electric force
- electromagnetic field
- electromagnet
- frequency
- induction
- insulator
- magnetic field
- magnetic field lines
- magnetic force
- permanent magnet
- polarity
- repulsion
- resistance
- voltage

Science Vocabulary Students Are Not Expected to Know

- Lorentz force
- electric potential
- electromotive force

Phenomena

Some example phenomena for MS-PS2-3:

- A radio emits music from its speakers. After a magnet in the speakers is removed, no sound can be heard.
- More electrical current is produced by a windmill when the wind speed is greater.
- Merchandise from a store that uses electromagnetic anti-shoplifting devices will set off an alarm at the exit if the tag is not removed.
- An electromagnet at a junkyard can lift old cars, while a homemade electromagnet cannot pick up much more than a few paper clips.

Performance Expectation MS-PS2-4

Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

Dimensions

Engaging in Argument from Evidence

- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for phenomenon or a solution to a problem.

PS2.B: Types of Interactions

- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass-e.g., Earth and the Sun.

Systems and System Models

- Models can be used to represent systems and their interactions (such as inputs, processes, and outputs) and energy and matter flows within systems.

Clarifications and Content Limits

Clarification Statements:

- Examples of evidence of arguments could include data generated from simulations or digital tools, and charts displaying mass, strength of interaction, distance from the sun, and orbital periods of objects within the solar system.

Content Limits:

- Assessment does not include Newton's Law of Gravitation or Kepler's Laws.
- Students do not need to know: mathematical representations of gravity (values, units, etc.).

Science Vocabulary Students Are Expected to Know Attraction

- gravity
- force
- mass
- attraction
- orbit
- magnitude
- galaxy
- solar system
- satellite
- force fields
- ellipse
- proportional
- kilogram
- proportionality
- attraction
- orbit
- period

Science Vocabulary Students Are Not Expected to Know

- terminal velocity
- relativity
- gravitational energy
- gravitational field
- magnetic field
- inverse square law

Phenomena

Some example phenomena for MS-PS2-4:

- The moon orbits Earth.
- Astronauts fall more slowly when jumping on the moon than on Earth.
- A dropped apple falls toward Earth, but not toward the moon.

Performance Expectation MS-PS2-5

Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

Dimensions

Planning and Carrying Out Investigations

- Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

PS2.B: Types of Interactions

- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Clarifications and Content Limits

Clarification Statements:

- Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls.
- Examples of investigations could include first-hand experiences or simulations.

Content Limits:

- Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.

Science Vocabulary Students Are Expected to Know Attraction

- attraction
- charge
- conductor
- electric charge
- electric current
- electric field
- electric force
- electromagnetic field
- electromagnet
- frequency
- induction
- insulator
- magnetic field
- magnetic field lines
- magnetic force
- permanent magnet
- polarity
- repulsion
- resistance
- voltage
- battery
- direction
- magnitude
- ampere
- charged particle
- volts
- gravity
- gravitational

Science Vocabulary Students Are Not Expected to Know

- Lorentz force
- electric potential
- electromotive force
- permeating
- vector field
- quantum property
- right-hand rule
- Ampere’s Law
- electrodynamics
- magnetic dipole
- Coulomb force
- electrostatic
- general relativity
- Laplace force

Phenomena

Some example phenomena for MS-PS2-5:

- A compass is opened and set on a table. The needle spins for a bit and then settles pointing north.
- Two blue-painted metal boxes sit on a table. With a pocket knife, a person easily scratches some of the paint off of one box, but they cannot remove the paint from the other box.
- A person walks across a carpeted floor in stocking feet. They touch another person who is sitting in a chair, delivering a large shock.
- A multimeter records the presence of an electric current when a coil rotates near a magnet.

Performance Expectation MS-PS3-1

Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Dimensions

Analyzing and Interpreting Data

- Construct and interpret graphical displays of data to identify linear and nonlinear relationships.

PS3.A: Definitions of Energy

- Motion energy is properly called kinetic energy. It is proportional to the mass of the moving object and grows with the square of the speed.

Scale, Proportion and Quantity

- Proportional relationships (e.g., speed as the ration of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed.

Content Limits:

- Students do not need to know: vectors such as velocity, the exact formula for the kinetic energy of an object or how to make calculations using the formula.

Science Vocabulary Students Are Expected to Know Attraction

- kinetic energy
- roll
- speed
- forms of energy
- mass
- magnitude
- motion energy
- proportional
- ratio
- square root
- independent variable
- dependent variable
- potential energy
- elastic collision
- inelastic collision

Science Vocabulary Students Are Not Expected to Know

- velocity
- vector
- inertial frame of reference
- acceleration
- deceleration
- relative motion
- Newtonian Mechanics

Phenomena

Some example phenomena for MS-PS3-1:

- Balls of different masses are dropped into a pile of snow. A graph of the mass vs. the depth of the indent is shown.
- A pendulum is dropped so that it hits a box on the ground. A graph of the drop height vs. the distance the box travels is shown.
- A ball thrown at a wall will bounce back a certain distance. A table of the speed of the ball vs. the distance it bounces back is given.
- Trains with differing amounts of train cars all come to a stop. A table of the number of the train cars vs. stopping distance is given.

Performance Expectation MS-PS3-2

Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Dimensions

Developing and Using Models

- Develop a model to describe unobservable mechanisms.

PS3.A: Definitions of Energy

- A system of objects may also contain stored (potential) energy, depending on their relative positions.

PS3.C: Relationship Between Energy and Forces

- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Systems and System Models

- Models can be used to represent systems and their interactions (such as inputs, processes, and outputs) and energy and matter flows within systems.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on relative amounts of potential energy, not on calculations of potential energy.
- Examples of objects within systems interacting at varying distances could include the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair.
- Examples of models could include representations, diagrams, pictures, and written descriptions of systems.

Content Limits:

- Assessment does not include calculations of kinetic and potential energy
- Assessment is limited to two objects and electric, magnetic, and gravitational interactions.

Science Vocabulary Students Are Expected to Know Attraction

- electron
- proton
- distribution of charged particles
- electrical charge
- negatively charged
- positively charged
- neutral
- neutrally charged
- polarity (magnetic)
- North Pole
- South Pole
- magnetic field
- electrical field
- attraction
- repulsion
- conductor
- insulator
- electromagnet

Science Vocabulary Students Are Not Expected to Know

- oscillation
- harmonic oscillator
- period
- momentum
- spring constant
- equilibrium position
- acceleration of gravity
- work
- power
- mechanical advantage
- Work-energy theorem
- rotation motion
- translational motion
- torque
- moment
- Coulomb's Law
- Faraday cage
- triboelectricity
- Law of Conservation of Energy
- electric potential
- gravitational potential

Phenomena

Some example phenomena for MS-PS3-2:

- A roller coaster track contains two hills of equal size. A roller coaster car sitting on the first hill is released and allowed to roll down the tracks of the first hill. The car comes to a stop before it reaches the top of the second hill.
- A pendulum never reaches a distance higher than the height at which it is released.
- The poles of an electromagnet can be reversed by reversing the electromagnet's connection to a battery.
- An empty shopping cart rolls down a hill in a parking lot and dents a parked car, while a full shopping cart rolls across a flat lot and does not damage a parked car.

Performance Expectation MS-PS3-3

Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Dimensions

Constructing Explanations and Designing Solutions

- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process, or system.

PS3.A: Definitions of Energy

- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy

- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system.

Clarifications and Content Limits

Clarification Statements:

- Examples of devices could include an insulated box and a Styrofoam cup.

Content Limits:

- Students should be given the problem to solve.
- Students do not need to know how to calculate energy of the system or change in energy.

Science Vocabulary Students Are Expected to Know Attraction

- thermal energy
- temperature
- kinetic energy
- energy transfer
- conductor
- insulator
- convection
- conduction
- radiation

Science Vocabulary Students Are Not Expected to Know

- Energy units (Joules, amperes)
- charged particles
- total energy
- stored energy

Phenomena

Some example phenomena for MS-PS3-3:

- Many cooks prefer pans that heat more evenly. Which materials should pans be made of?
- Design a more energy-efficient window.
- Choose the materials for a pot holder.

Performance Expectation MS-PS3-4

Plan an investigation to determine the relationships among energy transferred, type of matter, mass, and change in the average kinetic energy of particles, as measured by the temperature of a sample.

Dimensions

Planning and Carrying Out Investigations

- Plan an investigation individually and collaboratively and, in the design, identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurement will be recorded, and how many data are needed to support a claim.

PS3.A: Definitions of Energy

- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperatures and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy and Energy Transfer

- The amount of energy transfer needed to change the temperature of a sample of matter by a given amount depends on the nature of the matter, the size of the sample, and the environment.

Scale, Proportion, and Quantity

- Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Clarifications and Content Limits

Clarification Statements:

- Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature; the temperature change of samples of different materials with the same mass as they cool or heat in the environment; or the same material with different masses when a specific amount of energy is added.

Content Limits:

- Assessment does not include calculating the total amount of thermal energy transferred.

Science Vocabulary Students Are Expected to Know

- cold
- hot
- sun
- sunlight
- cool
- environment
- heat
- temperature
- warm
- liquid
- melt
- state
- surrounding
- volume
- collide
- collision
- heat conduction
- particle
- stored energy
- transfer
- average
- mass
- thermal
- kinetic energy
- proportional
- ratio
- thermal energy

Science Vocabulary Students Are Not Expected to Know

- stable
- thermal equilibrium
- thermodynamics

Phenomena

Some example phenomena for MS-PS3-4:

- A mug of hot coffee is set on a cork coaster. After letting the mug of coffee sit for a while, a person picks up the mug and the coaster and notices that both the mug and coaster are warm.
- When placed over the same heat source, water takes longer to reach 100°C than a cola soft drink.
- Pot holders work well when they are dry. When they are wet, they don’t.
- A metal spoon used to stir a hot beverage gets hot much more quickly than a wooden spoon.
- When cold rain hits a freezing sidewalk, the rain turns to ice.
- When placed over the same heat, a metal pot boils water faster than a glass pot.

Performance Expectation MS-PS3-5

Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Dimensions

Engaging in Argument for Evidence

- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon.

PS3.B: Conservation of Energy and Energy Transfer

- When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time.

Energy and Matter

- Energy may take different forms (e.g., energy in fields, thermal energy, and energy of motion).

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on understanding that when the kinetic energy of an object increases or decreases, the energy (e.g., kinetic, thermal, potential, light, sound) of other objects or the surroundings within the system increases or decreases, indicating that energy was transferred to or form the object.
- Emphasis is on knowing that temperature is the measure of the average kinetic energy of particles of matter.
- Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of an object.

Content Limits:

- Assessment does not include any calculations of energy or energy flow.

Science Vocabulary Students Are Expected to Know

- kinetic energy
- potential energy
- heat energy
- transfer of energy
- conservation of energy
- closed system
- open system
- friction
- joule
- force
- push
- pull
- transformation of energy
- mass
- thermometer
- Fahrenheit
- Celsius
- pendulum
- sound energy

Science Vocabulary Students Are Not Expected to Know

- co-efficient of kinetic energy
- air resistance
- work
- energy efficiency
- chemical energy
- electrical energy
- machine (for transforming energy)
- mechanical energy

Phenomena

Some example phenomena for MS-PS3-5:

- The Riverside geyser in the Upper Geyser Basin at Yellowstone National Park throws out jets of hot water into the air at regular intervals.
- Bowling pins fall over and start to roll when struck by a bowling ball.
- A hot air balloon lifts off the ground as the burner is lit under the balloon.

Performance Expectation MS-PS4-1

Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

Dimensions

Using Mathematics and Computational Thinking

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

Patterns

- Graphs and charts can be used to identify patterns in data.

Clarifications and Content Limits

Clarification Statements:

- Emphasize describing waves with both quantitative and qualitative thinking.
- Examples could include using graphs, charts, computer simulations, or physical models to demonstrate amplitude and energy correlation.
- All equations and formulas must be provided and be age-appropriate.

Content Limits:

- Assessment does not include electromagnetic waves and is limited to standard repeating waves.
- Assessment does not include identifying or knowing characteristics of different types of waves (mechanical, electromagnetic, sonic, etc.).
- Students do not need to know how two waves carrying the same energy can have different amplitudes when introduced into materials of different densities and elasticities.

Science Vocabulary Students Are Expected to Know

- speed
- force
- kinetic energy
- proportional
- sound wave
- frequency
- resting position
- medium
- wavelength

Science Vocabulary Students Are Not Expected to Know

- elastic
- seismic wave
- crest
- trough
- oscillate

Phenomena

Some example phenomena for MS-PS4-1:

- The 1896 Sanriku earthquake off the coast of Japan generated ocean waves that reached a height of 100 feet (30 m).
- Compared to a megaphone that sends sound messages up to 300 meters away, a Long Range Acoustic Device (LRAD) sends messages that can be heard up to 5,500 meters away.
- Scientists at the Swiss Federal Institute in Zurich caused a toothpick to levitate using sound waves.
- A wave travels down a rope from one student to another when the first student shakes it.

Performance Expectation MS-PS4-2

Develop and/or use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Dimensions

Developing and Using Models

- Develop and/or use a model to predict and/or describe phenomena.

PS4.A: Wave Properties

- A sound wave needs a medium through which it is transmitted.

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass), where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.
- This includes amplitudes, frequencies, and wave lengths.

Content Limits:

- Assessment is limited to qualitative applications pertaining to light and mechanical waves.
- Qualitative models, not quantitative.
- Particle movement and compression waves are not to be assessed at this level.
- Constructive/destructive interference are not to be assessed.

Science Vocabulary Students Are Expected to Know

- reflected
- absorbed
- transmitted
- refracted
- medium
- transparent
- frequency
- brightness
- color
- bending
- amplitude
- sound wave
- light wave
- path
- propagation
- matter
- filter
- barrier
- lens
- mirror
- mechanical waves
- electromagnetic
- visible light
- ray
- prism
- wavelength

Science Vocabulary Students Are Not Expected to Know

- longitudinal wave
- transverse wave
- compression wave
- seismic wave
- radio wave
- microwave
- infrared
- ultraviolet
- X-rays
- gamma rays
- angle of incidence
- concave
- convex
- diffraction
- constructive interference
- destructive interference

Phenomena

Some example phenomena for MS-PS4-2:

- One part of a straw appears to be broken from the rest of the straw when viewed through the side of a glass of water.
- Music placed near a lake can be heard clearly while sitting on the shore. However, while swimming under the water, the sound cannot be heard as clearly.
- Objects are more visible during a moonlit night when there is snow on the ground vs. when there is no snow on the ground.
- Loud music moves the leaves of a plant.
- Whisper Corners in the Capitol Building.

Performance Expectation MS-PS4-3

Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.

Dimensions

Obtaining, Evaluating, and Communicating Information

- Integrate qualitative scientific and technical information in written test with information contained in media and visual displays to clarify claims and findings.

PS4.C: Information Technologies and Instrumentation

- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

Structure and Function

- Structures can be designed to serve particular functions.

Clarifications and Content Limits

Clarification Statements:

- Emphasis is on a basic understanding that waves can be used for communication purposes.
- Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.
- Examples could also include using vinyl record vs. digital song files, film cameras vs. digital cameras, or alcohol thermometers vs. digital thermometers.

Content Limits:

- Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.
- Students do not need to know:
    - Specifics about binary or any other coding process
    - How certain mechanisms work other than the fact that they are either analog or digital
    - Students are not responsible for knowing the different parts of mechanisms: hard drives, USB cables, flash drives, and servers.

Science Vocabulary Students Are Expected to Know

- computer
- machine
- communicate
- electricity
- device
- coded
- decode
- conversion
- convert
- digitize
- transfer
- wave
- encode
- radio wave
- transmission
- radio wave

Science Vocabulary Students Are Not Expected to Know

- binary
- frequency
- electron
- emit
- photoelectric
- pixel
- electromagnetic radiation
- radiation
- wave packet
- wave source
- ohm
- photon
- microwave
- ultraviolet
- volt
- ampere

Phenomena

Some example phenomena for MS-PS4-3:

- The equivalent of hundreds of vinyl records can be stored within a portable music player.
- Music sounds clearer on a portable music player than it does on a record player (less noise interference).
- Digital data can be copied hundreds of times without loss of quality, while it is much harder to retain the quality of analog data.