Crosscutting Concepts in the Next Generation Science Standards

A Framework for K-12 Science Education identifies seven crosscutting concepts that are meant to give students an organizational structure to understand the world and helps students make sense of and connect core ideas across disciplines and grade bands. They are not intended as additional content. Listed below are the crosscutting concepts from the *Framework*:

1. Patterns
2. Cause and Effect
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter in Systems
6. Structure and Function
7. Stability and Change of Systems

As with the Science and Engineering Practices (SEP), the *Framework* does not specify grade-band endpoints for the crosscutting concepts, but instead provides a summary of what students should know by the end of grade twelve and a hypothetical progression for each. To assist with writing the Next Generation Science Standards (NGSS), grade-band endpoints were constructed for the SEP and crosscutting concepts (CCC) that are based on these hypothetical progressions and 12th grade endpoints. These representations of the CCC appear in the NGSS and supporting foundation boxes. In Section I below, a description of the crosscutting usage by grade band illustrates how the crosscutting concepts bring the knowledge together. Section II is a complete listing of the specific CCC used in the NGSS.

Section 1: Description of CCC usage by Grade Band

Patterns:

<u>K-2</u>

In the K-2 grade band, students can use observations of patterns in the natural and human designed world to describe phenomena and provide evidence. Examples from **Life Science** include using data to describe the patterns of what plants and animals need to survive (K-LS1-a). Examples from **Physical Science** include using information from observations to support the explanation that different individual plants and animals of the same type have similarities and differences. Examples from **Earth and Space Science** include using observations to describe patterns of objects in the sky that are cyclic and can be predicted (1-ESS1-a).

[Performance Expectations using Patterns in K-2: K-PS1-a, K-PS1-c, K-LS1-a, K-ESS2-a, K-ESS2-b, 1-LS3-a, 1-LS1-c, 1-LS1-d, 1-ESS1-a, 1-ESS1-c, 2-ESS2-e.]

3-5

In the 3-5 grade band, students can observe similarities and differences in patterns to sort and classify natural and human designed phenomena. Simple rates of change and cyclic patterns of change for these phenomena can be analyzed and used in to make predictions. Examples from **Life Science** include using evidence to support the idea that patterns of traits pass from parents to offspring and are influenced by environmental patterns (3-LS3-a). Examples from **Physical Science** include developing a model to describe patterns produced by waves in terms of amplitude and wavelength (4-PS4-a). Examples from **Earth and Space Science** include using standard units to record local weather data to identify day-to-day and long-term patterns of weather (3-ESS2-a).

[Performance Expectations using Patterns in 3-5: 3-LS1-a, 3-LS3-a, 3-ESS2-a, 4-PS4-a, 4-ESS1-a, 4-ESS2-c, 5-ESS1-b., 5-ESS1-c]

6-8

In the 6-8 grade band, macroscopic patterns are related to the nature of microscopic and atomic level structure. Students can observe patterns in rates of change and other numerical relationships to provide information about natural and human designed systems, as well as identify cause and effect relationships. These patterns and relationships can often be identified in data using graphs and charts.

Examples from **Life Science** include constructing explanations for the anatomical similarities and differences between fossils of once living organisms and organisms living today, then relating these explanations to the assumption that events in natural systems occur in consistent patterns (MS-LS4-c). Examples from **Physical Science** include developing models of a variety of substances, from those having simple patterns of molecules to those with extended structures (MS-PS1-a). Examples from **Earth and Space Science** include developing and using models of tectonic plate motions to explain patterns in the fossil record, rock record, continental shapes, and seafloor structures (MS-ESS2-e).

[Performance Expectations using Patterns in 6-8: MS-PS1-a, MS-PS1-e, MS-LS2-d, MS-LS2-h, MS-LS4-a, MS-LS4-c, MS-LS4-d, MS-ESS1-a, MS-ESS2-e, MS-ESS2-f, MS-ESS3-h.]

9-12

In the 9-12 grade band, students may observe patterns at multiple scales of systems. Some of these patterns are identified using mathematical representations. Information about these patterns is used to provide evidence for causal explanations of phenomena, but students learn that classifications or explanations used at one scale may fail or need revision at a smaller or larger scale and therefore require improved investigations and experiments. Patterns of the performance of designed systems can be analyzed and interpreted to reengineer and improve the systems.

Examples from **Life Science** include using a model to explain how mitotic cell division results in daughter cells with identical patterns of genetic material essential for producing and maintaining a complex organism (HS-LS1-e). Examples from **Physical Science** include constructing an explanation using the structure of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties to support predictions about the outcome of simple chemical reactions (HS-PS1-i). Examples from **Earth and Space Science** include constructing explanations, using the theory of plate tectonics, for patterns in the general trends of the ages of both the continental and oceanic crust (HS-ESS1-h).

[Performance Expectations using Patterns in 9-12: HS-PS1-i, HS-LS1-e, HS-LS1-l, HS-LS4-a, HS-LS4-c, HS-LS4-f, HS-ESS1-h.]

Cause and Effect:

K-2

In the K-2 grade band, students learn that events have causes that generate observable patterns, and simple tests can be designed to gather evidence that supports or refutes their ideas about causes. Examples from **Life Science** include communicating and discussing solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment using models and/or drawings (K-ESS3-d). Examples from **Physical Science** include carrying out investigations to determine the effect of placing objects with different characteristics in the path of a beam of light and use these characteristics to meet a goal (1-PS4-d). Examples from **Earth and Space Science** include using drawings and physical models to test, compare strengths and weaknesses, and communicate design solutions that slow or prevent wind and/or water from changing the shape of the land.

[Performance Expectations using Cause and Effect in K-2: K-PS1-b, K-PS3-a., K-PS3-b, K-ESS3-b, K-ESS3-c, K-ESS3-d, 1-PS4-a, 1-PS4-b, 1-PS4-c, 1-PS4-d, 2-PS2-a, 2-PS2-b, 2-PS2-c, 2-PS3-a, 2-PS3-b, 2-LS2-b, 2-ESS2-a, 2-ESS2-d, 2-ESS2-f.]

3-5

In the 3-5 grade band, students can routinely identify and test cause and effect relationships and use them to explain change. Students can consider that events that regularly occur together may or may not be part of a cause and effect relationship. Examples from **Life Science** include constructing explanations for how differences in characteristics of some individuals in the same species affect their ability to survive, find mates, and reproduce (3-LS4-b). Examples from **Physical Science** include investigating the effect of electric and magnetic forces between objects not in contact with each other to explain their relationships (3-PS2-c). Examples from **Earth and Space Science** include planning and carrying out fair tests on the effects of water, ice, wind, and vegetation on the relative rate of weathering and erosion (4-ESS2-a).

[Performance Expectations using Cause and Effect in 3-5: 3-PS2-a, 3-PS2-c, 3-LS4-b, 4-ESS2-a, 4-PS4-c, 5-PS1-d, 5-PS1-e, 5-ESS1-a, 5-ESS3-b.]

6-8

In the 6-8 grade band, students can classify relationships as causal or correlational and understand that correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural and designed systems. Students understand that some phenomena have more than one cause, and some cause and effect relationships may only be described using probability.

Examples from **Life Science** include using empirical evidence to support an argument for how characteristic animal behaviors affect the probability of successful reproduction (MS-LS1-e). Examples from **Physical Science** includes developing a molecular model that depicts and predicts why either temperature change and/or change of state can occur when adding or removing thermal energy from a pure substance (MS-PS1-c). Examples from **Earth and Space Science** include collecting data and generating evidence to show how changes in weather conditions result from the motions and interactions of air masses (MS-ESS2-i).

[Performance Expectations using Cause and Effect in 6-8: MS-PS1-c, MS-PS2-c, MS-PS2-e, MS-LS1-e, MS-LS1-f, MS-LS1-g, MS-LS1-h, MS-LS1-i, MS-LS2-a, MS-LS3-a, LS4-b, MS-LS4-e, MS-LS4-f, MS-LS4-j, MS- MS-LS1-l, MS-ESS2-i, MS-ESS2-m,MS-ESS2-p, MS-ESS3-b, MS-ESS3-e, MS-ESS3-f.]

9-12

In the 9-12 grade band, students can use empirical evidence to differentiate between instances of causation and correlation and can make claims about specific causes and effects. Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. Students can design systems to cause a desired effect and understand that changes in systems may have various causes that may not have equal effects.

Examples from **Life Science** include obtaining, evaluating and communicating information that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) environmental factors (HS-LS3-b). Examples from **Physical Science** include analyzing data to support the claim that Newton's second law of motion describes the mathematical relationship between the net force on macroscopic objects, their mass, and their acceleration (HS-PS2-a). Examples from **Earth and Space Science** include using geoscience data and the results from global climate models to make evidence-based forecasts of climate change (HS-ESS3-g).

[Performance Expectations using Cause and Effect in 9-12: HS-PS1-b, HS-PS1-d, HS-PS2-a, HS-PS2-c, HS-PS2-e, HS-PS3-e, HS-LS1-f, HS-LS2-k, HS-LS3-a, HS-LS3-b, HS-LS3-d, HS-LS4-b, HS-LS4-d, HS-LS4-e, HS-ESS1-d, HS-ESS2-h, HS-ESS3-c, HS-ESS3-g.]

Scale, Proportion, and Quantity:

K-2

In the K-2 grade band, students can use standard units to measure length and describe objects using relative scale (e.g., bigger and smaller; hotter and colder). Examples from **Physical Science** include distinguishing arguments that some changes caused by heating or cooling can be reversed and some cannot based on whether they are supported by evidence (2-PS1-d), or analyzing data from tests of a student-designed tool to determine if the tool measures weight or size accurately compared to standard measuring tools. (2-PS1-c).

[Performance Expectations using Scale, Proportion, and Quantity in K-2: 2-PS1-c, 2-PS1-d.]

3-5

In the 3-5 grade band, students learn that natural objects and observable phenomena exist from the very small to the immensely large. Students can use standard units to measure and describe physical qualities (e.g., weight, time, temperature, and volume). Examples from **Physical Science** include making observations and measurements to identify given materials (e.g., metal and baking soda) based on their properties (5-PS1-c). Examples from **Earth and Space Science** include interpreting provided data about the relative distances of the sun and other stars from Earth to explain the difference in their apparent brightness (5-PS2-a).

[Performance Expectations using Scale, Proportion, and Quantity in 3-5: 5-PS1-c, 5-PS2-a.]

6-8

In the 6-8 grade band, students can observe time, space, and energy at various scales using models. Scientific relationships can be represented using algebraic expressions and equations. Students can recognize that the function of natural and designed systems may change with scale, and phenomena that can be observed at one scale may not be observable at another scale. Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) are used to provide information about the magnitude of properties and processes.

Examples from **Life Science** include planning and carrying out an investigation to provide evidence that living things are made of cells that can be observed at various scales (MS-LS1-a). Examples from **Physical Science** include designing an experiment to produce empirical evidence supporting the claim that the change in the motion of an object depends on the sum of the forces on the object and the mass of the object (MS-PS2-b). Examples from **Earth and Space Science** include constructing scale models of the geologic time scale to depict the relative timing of major events in Earth's history (MS-ESS1-f).

[Performance Expectations using Scale, Proportion, and Quantity in 6-8: MS-PS2-b, MS-PS2-d, MS-PS3-a, MS-PS3-b, MS-LS2-g, MS-LS1-a, MS-ESS1-c, MS-ESS1-e, MS-ESS1-f, MS-ESS1-g.]

9-12

In the 9-12 grade band, students learn that the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. Students learn that some systems can only be studied indirectly as they are too small, large, fast or slow to observe directly, and patterns observable at one scale may not be observable or exist at other scales. The concept of orders of magnitude can be used to understand how a model at one scale relates to a model at another scale, and algebraic thinking is used to predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Examples from **Life Science** include planning and carrying out an investigation to make mathematical comparisons of factors affecting carrying capacity and biodiversity of similar ecosystems at different scales (HS-LS2-a). Examples from **Earth and Space Science** include analyzing actual or simulated isotope ratios within Earth materials to make scientific claims about the planet's age, the ages of Earth events and rocks, and the overall time scale of Earth's history (HS-ESS1-g).

[Performance Expectations using Scale, Proportion, and Quantity in 9-12: HS-LS2-a, HS-LS2-b, HS-LS3-d, HS-ESS1-a, HS-ESS1-g, HS-ESS1-i, HS-ESS2-a, HS-ESS2-f.]

Systems and System Models:

K-2

In the K-2 grade band, students can describe objects and organisms in terms of their parts. Students learn that systems in the natural and designed world have parts that work together. Examples from **Life Science** include making observations about the variety of plants and animals living in an area in order to make comparisons between different areas (2-LS4-a), or developing and using models to compare how living things depend on their surroundings to meet their needs in the places they live (2-LS2-a).

[Performance Expectations using System and System Models in K-2: K-ESS3-a, 2-LS2-a, 2-LS4-a.]

3-5

In the 3-5 band, students learn that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. Students can describe a system in terms of its components and interactions. Examples from **Life Science** using evidence about organisms in their natural habitats to design an artificial habitat in which the organisms can survive well (3-LS4-e). Examples from **Earth and Space Science** include using models to describe interactions between the geosphere, hydrosphere, atmosphere, and biosphere and identify the limitations of the models (5-ESS2-a).

[Performance Expectations using System and System Models in 3-5: 3-LS4-d, 3-LS4-e, 5-LS2-c 5-ESS2-a, 5-ESS2-b, 5-ESS3-a.]

6-8

In the 6-8 grade band, students learn that systems may interact with one another, and systems may have sub-systems and may be part of larger complex systems. Students can use models to represent systems and their interactions, and they understand that models are limited in their ability to represent only certain aspects of the system under study.

Examples from **Life Science** include using a model of managed ecosystems to evaluate and improve proposals to maintain ecosystem biodiversity (MS-LS4-i). Examples from **Physical Science** include constructing and presenting arguments to support the claim that gravitational interactions determine the motion of systems of objects in space (MS-PS2-c). Examples from **Earth and Space Science** include using models of oceanic and atmospheric circulation to construct explanations for the development of local and regional climates (MS-ESS2-j).

[Performance Expectations using System and System Models in 6-8: MS-PS2-a, MS-PS2-d, MS-PS2-e, MS-LS1-b, MS-LS2-f, MS-LS4-i, MS-ESS1-b, MS-ESS2-j, MS-ESS2-l, MS-ESS3-i.]

9-12

In the 9-12 grade band, students can design models to do specific tasks. They can define the boundaries and initial conditions of a system and analyze its inputs and outputs using various models. Some of these models (e.g., physical, mathematical, computer) can also be used to simulate systems and the interactions—including energy, matter, and information flow—within and between systems at different scales. While students can use models to predict the behavior of a system, they understand that these predictions have limited precision and reliability due to assumptions and approximations inherent in models.

Examples from **Life Science** include providing evidence to support an explanation that elements and energy are conserved as matter cycles and energy flows through ecosystems (HS-LS2-e). Examples from **Physical Science** include use mathematical expressions to explain, model, or simulate the change energy in the energy of one component within a closed system when the change in the energy of the other component(s) is known (HS-PS3-a). Examples from **Earth and Space Science** include using models of Earth system interactions to explain the relationships among the hydrosphere, atmosphere, cryosphere, geosphere, and biosphere systems and how they are being modified in response to human activities (HS-ESS3-i).

[Performance Expectations using System and System Models in 9-12: HS-PS1-a, HS-PS2-b, HS-PS3-a, HS-PS3-c, HS-PS3-d, HS-LS1-g, HS-LS2-e, HS-LS1-c, HS-ESS1-f, HS-ESS2-j, HS-ESS3-i.]

Energy and Matter in Systems:

K-2

In the K-2 grade band, students learn that objects may break into smaller pieces, be put together into larger pieces, or change shapes. Examples from **Physical Science** include designing an object built from a small set of pieces to solve a problem and compare solutions designed by peers given the same set of pieces (2-PS1-b)

[Performance Expectations using Energy and Matter in Systems in K-2: 2-PS1-b.]

3-5

In the 3-5 grade band, students learn that matter is made of particles and energy can be transferred in various ways and between objects. Students observe the conservation of matter by tracking matter flows and cycles before and after processes and recognizing that the total weight of substances does not change. Examples from **Life Science** include constructing and using models of food webs to describe the transfer of matter among plants, animals, decomposers, and the environment (5-LS2-a). Examples from **Physical Science** include using simple models to describe that regardless of what reaction or change in properties occur, the total weight of the substances involved does not change (5-PS1-b).

[Performance Expectations using Energy and Matter in Systems in 3-5: 4-PS3-a, 4-PS3-b, 4-PS3-c, 4-PS3-d, 4-PS3-e, 4-PS4-b, 5-PS1-a, 5-PS1-b, 5-PS3-a, 5-LS2-a, 5-LS2-b, 5-LS2-d.]

6-8

In the 6-8 grade band, students learn that matter is conserved because atoms are conserved in physical and chemic processes. Students learn that energy may take different forms (e.g., energy field, thermal energy, energy of motion), and they can track the energy transfer/energy flows through a designed or natural system. Students learn that this energy transfer drives the motion and/or cycling of matter within systems.

Examples from **Life Science** include using evidence to construct explanations for the role of photosynthesis in the cycling of matter and flow of energy on Earth (MS-LS1-j). Examples from **Physical Science** include construct molecular models of reactants and products to show that atoms —and therefore mass— are conserved in a chemical reaction (MS-PS1-d). Examples from **Earth and Space Science** include posing models to describe mechanisms for the cycling of water through Earth's systems as it changes phase and moves in response to energy from the sun and the force of gravity (MS-ESS2-b).

[Performance Expectations using Energy and Matter in Systems in 6-8: MS-PS1-d, MS-PS1-g, MS-PS3-c, MS-PS3-e, MS-PS3-f, MS-LS1-j, MS-LS1-k, MS-LS2-b, MS-LS2-e, MS-ESS2-a, MS-ESS2-b, MS-ESS2-c, MS-ESS2-h, MS-ESS2-k, MS-ESS2-n.]

9-12

In the 9-12 grade band, students learn that the total amount of energy and matter in closed systems is conserved and that energy cannot be created or destroyed—only moved between places, objects, or systems. Students understand that energy drives the cycling of matter within and between systems, and they can describe changes of energy in a system in terms of energy and matter flows into, out of, and within that system. Students learn that in nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Examples from **Life Science** include using a model to explain cellular respiration as a chemical process whereby the bonds of food molecules and oxygen molecules are broken and bonds in new compounds are formed resulting in a net transfer of energy (HS-LS1-j). Examples from **Physical Science** include constructing representations of the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay (HS-PS1-j). Examples from **Earth and Space Science** include constructing, revising, and using models of atmospheric circulation to explain how air masses redistribute energy from the sun (HS-ESS2-g).

[Performance Expectations using Energy and Matter in Systems in 9-12: HS-PS1-f, HS-PS1-h, HS-PS1-j, HS-LS1-h, HS-LS1-i, HS-LS1-j, HS-LS2-c, HS-LS2-d, HS-LS2-f, HS-LS2-g, HS-ESS1-b, HS-ESS1-c, HS-ESS2-d, HS-ESS2-g, HS-ESS2-i, HS-ESS2-k.]

Structure and Function:

K-2

In the K-2 grade band, students relate the shape and stability of natural and designed objects to their function(s). Examples from **Physical Science** include using diagrams and physical models to support the explanation of how the external parts of animals and plants help them survive (1-LS1-a), or defining a human problem and designing a solution to the problem based on how animals use external parts to meet their own needs (1-LS1-b).

[Performance Expectations using Structure and Function in K-2: 1-LS1-a, 1-LS1-b.]

3-5

In the 3-5 grade band, students learn that different materials have different substructures, which can sometimes be observed. These substructures have shapes and parts that serve functions. Examples from **Physical Science** include constructing models to describe that animals' senses receive different types of information from their environment, process it in the brain, and respond to the information in different ways (4-LS1-c), or designing, testing, and comparing solutions that replace or enhance the function of an external animal structure necessary for survival (4-LS1-b).

[Performance Expectations using Structure and Function in 3-5: 4-LS1-b, 4-LS1-c.]

6-8
In the 6-8 grade band, students can visualize and model complex and microscopic structures to describe how their function depends on shapes, composition, and relationships among these structures' parts. Students can use this information to analyze complex natural and designed structures to determine how they function, and they can design their own structures to serve particular functions by taking into account properties of different materials.

Examples from **Life Science** include applying scientific knowledge to explain that changes (mutations) to genes located on chromosomes affect proteins and may result in harmful, beneficial or neutral effects to the structure and function of the organism (MS-LS3-b). Examples from **Physical Science** include or constructing an explanation using a wave model of light for why materials may look different depending on the composition of the material and the wavelength and amplitude of the light that shines on them (MS-PS4-c).

[Performance Expectations using Structure and Function in 6-8: MS-PS1-b, MS-PS4-a, MS-PS4-b, MS-PS4-c, MS-LS1-c, MS-LS1-m, MS-LS3-b.]

9-12
In the 9-12 grade band, students can perform detailed examinations of properties of different materials, structures of different components, and connections of components. These examinations reveal the materials' function and/or solve a problem. Students can infer the functions and properties of designed objects from their overall structure, the way the objects' components are shaped and used, and the molecular structure of the objects' materials.

Examples from **Life Science** include obtaining, evaluating, and communicating information about how DNA sequences determine the structure and function of proteins, which carry out most of the work of the cell (HS-LS1-b). Examples from **Physical Science** include constructing an explanation of how photovoltaic materials work using the particle model of light, and describe their application in everyday devices (HS-PS4-h). Examples from **Earth and Space Science** include applying scientific reasoning to show how empirical evidence from Earth observations and laboratory experiments has been used to develop the current model of Earth's interior structures (HS-ESS2-c).

[Performance Expectations using Structure and Function in 9-12: HS-PS1-c, HS-PS2-f, HS-PS4-a, HS-PS4-b, HS-PS4-d, HS-PS4-e, HS-PS4-f, HS-PS4-g, HS-PS4-h, HS-LS1-a, HS-LS1-b, HS-LS3-b, HS-ESS2-c.]

Stability and Change of Systems:
K-2
In the K-2 grade band, students learn that some things stay the same while other things change, and these changes may occur slowly or rapidly. Examples from **Life Science** include designing a solution to a problem caused when a habitat changes and some of the plants and animals may no longer be able to live there (2-LS2-c). Examples from **Physical Science** include developing

models to investigate how wind and water can move Earth materials from one place to another and change the shape of the land quickly or slowly (2-ESS2-b).

[Performance Expectations using Stability and Change of Systems: 2-LS2-c, 2-ESS2-b, 2-ESS2-c.]

3-5

In the 3-5 grade band, students can measure change in terms of differences over time or at different rates. Students learn that some systems appear stable, but over long periods of time will eventually change. Examples from **Life Science** include analyzing and interpreting data from fossils to describe the types of organisms that lived long ago and the environments in which they lived and compare them with organisms and environments today (3-LS4-e). Examples from **Physical Science** include investigating the motion of objects across time to determine when a consistent pattern can be observed and used to predict future motions in the system (3-PS2-b), or

[Performance Expectations using Stability and Change of Systems in 3-5: 3-PS2-b, 3-LS2-a, 3-LS4-a.]

6-8

In the 6-8 grade band, students can construct explanations of stability and change in natural or designed systems by examining the changes over time and forces at different scales, including the atomic scale. Students learn that changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time.

Examples from **Life Science** include obtaining, evaluating and communicating information about how two populations of the same species in different environments have evolved to become separate species (MS-LS4-h). Examples from **Physical Science** include defining a problem that can be solved through the development of a simple system that requires the periodic application of a force initiated by a feedback mechanism to maintain a stable state (MS-PS2-f). Examples from **Earth and Space Science** include constructing explanations from evidence for how different geoscience processes, over widely varying scales of space and time, have shaped Earth's history (MS-ESS2-d).

[Performance Expectations using Stability and Change of Systems in 6-8: MS-PS2-f, MS-LS2-c, MS-LS2-I, MS-LS4-h, MS-ESS2-d, MS-ESS2-g, MS-ESS2-o, MS-ESS3-k.]

9-12

In the 9-12 grade band, students learn that much of science deals with constructing explanations of how things change or remain the same. Students also learn that change and rates of change can be quantified and modeled over very short or very long periods of time. They understand that feedback can stabilize or destabilize a system and systems can be designed for greater or lesser stability, and some system changes are irreversible.

Examples from **Life Science** include engaging in argument from evidence about the effects of modest and extreme biological or physical changes to ecosystems and the natural capacity to reestablish an ecosystem with more or less stable conditions (HS-LS2-i). Examples from **Physical Science** include Refining the design of a chemical system to specify changes in conditions that would produce increased amounts of products at equilibrium. Examples from **Earth and Space Science** include analyzing data regarding the effects of human activities on natural systems to make valid scientific claims for how engineering solutions are designed and implemented to help limit environmental impacts. (HS-ESS3-f).

[Performance Expectations using Stability and Change of Systems in 9-12: HS-PS1-e, HS-PS1-g, HS-PS3-g, HS-LS1-d, HS-LS2-h, HS-LS2-i, HS-LS2-j HS-LS2-l, HS-ESS1-d, HS-ESS1-j, HS-ESS1-l, HS-ESS2-b, HS-ESS2-e, HS-ESS3-f.]

NGSS Crosscutting Concepts*

Section 2:Crosscutting Concepts Matrix

1. Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	▪ Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena and designed products. ▪ Cyclic patterns of change related to time can be used to make predictions.	▪ Macroscopic patterns are related to the nature of microscopic and atomic-level structure. ▪ Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. ▪ Patterns can be used to identify cause and effect relationships. ▪ Graphs and charts can be used to identify patterns in data.	▪ Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ▪ Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. ▪ Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. ▪ Mathematical representations are needed to identify some patterns. ▪ Empirical evidence is needed to identify patterns.

2. Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Events have causes that generate observable patterns. ▪ Simple tests can be designed to gather evidence to support or refute student ideas about causes.	▪ Cause and effect relationships are routinely identified, tested, and used to explain change. ▪ Events that occur together with regularity might or might not be a cause and effect relationship.	▪ Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. ▪ Cause and effect relationships may be used to predict phenomena in natural or designed systems. ▪ Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ▪ Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. ▪ Systems can be designed to cause a desired effect. ▪ Changes in systems may have various causes that may not have equal effects.

* Adapted from: National Research Council (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academy Press. Chapter 4: Crosscutting Concepts.

NGSS Crosscutting Concepts*

3. Scale, Proportion, and Quantity – In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Relative scales allow objects to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). ▪ Standard units are used to measure length.	▪ Natural objects and observable phenomena exist from the very small to the immensely large. ▪ Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.	▪ Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. ▪ The observed function of natural and designed systems may change with scale. ▪ 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. ▪ Scientific relationships can be represented through the use of algebraic expressions and equations. ▪ Phenomena that can be observed at one scale may not be observable at another scale.	▪ The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ▪ Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. ▪ Patterns observable at one scale may not be observable or exist at other scales. ▪ Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. ▪ Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

4. Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Objects and organisms can be described in terms of their parts. ▪ Systems in the natural and designed world have parts that work together.	▪ A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. ▪ A system can be described in terms of its components and their interactions.	▪ Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. ▪ Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. ▪ Models are limited in that they only represent certain aspects of the system under study.	▪ Systems can be designed to do specific tasks. ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. ▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. ▪ Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

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5. Energy and Matter: Flows, Cycles, and Conservation – Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Objects may break into smaller pieces, be put together into larger pieces, or change shapes.	▪ Matter is made of particles. ▪ Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. ▪ Energy can be transferred in various ways and between objects.	▪ Matter is conserved because atoms are conserved in physical and chemical processes. ▪ Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. ▪ Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). ▪ The transfer of energy can be tracked as energy flows through a designed or natural system.	▪ The total amount of energy and matter in closed systems is conserved. ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. ▪ Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. ▪ Energy drives the cycling of matter within and between systems. ▪ In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

6. Structure and Function – The way an object is shaped or structured determines many of its properties and functions.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ The shape and stability of structures of natural and designed objects are related to their function(s).	▪ Different materials have different substructures, which can sometimes be observed. ▪ Substructures have shapes and parts that serve functions.	▪ 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 its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they 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.	▪ Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. ▪ The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

7. Stability and Change – For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Some things stay the same while other things change. ▪ Things may change slowly or rapidly.	▪ Change is measured in terms of differences over time and may occur at different rates. ▪ Some systems appear stable, but over long periods of time will eventually 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, including the atomic scale. ▪ Small changes in one part of a system might cause large changes in another part. ▪ Stability might be disturbed either by sudden events or gradual changes that accumulate over time. ▪ Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.	▪ Much of science deals with constructing explanations of how things change and how they remain stable. ▪ Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. ▪ Feedback (negative or positive) can stabilize or destabilize a system. ▪ Systems can be designed for greater or lesser stability.

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