Middle School Earth and Space Science CCCs (Discipline Specific Model)

PATTERNS In grades 6-8, students recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure. They identify patterns in rates of change and other numerical relationships that provide information about natural and human designed systems. They use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data.

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

MS-ESS2-3

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

MS-ESS1-1

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

MS-ESS3-2

CAUSE AND EFFECT: MECHANISM AND PREDICTION In grades 6-8, students classify relationships as causal or correlational and recognize that correlation does not necessarily imply causation. They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

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

MS-ESS3-3

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

MS-ESS2-5; MS-ESS3-1; MS-ESS3-4

SCALE, PROPORTION, AND QUANTITY In grades 6-8, students observe time, space and energy phenomena at various scales using models to study systems that are too large or too small. They understand phenomena observed at one scale may not be observable at another scale and that the function of natural and designed systems may change with scale. They use proportional relationships (e.g., speed as the ratio of distance traveled to time taken) to gather information about the magnitude or properties and processes. They represent scientific relationships through the use of algebraic expressions and equations.

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

MS-ESS1-3; MS-ESS1-4; MS-ESS2-2

SYSTEMS AND SYSTEM MODELS In grades 6-8, students understand that systems may interact with other systems; they may have sub-systems, and be part of larger complex systems. They can use models to represent systems and their interactions – such as inputs, processes, and outputs – and energy, matter and information flows within systems. They also learn that models are limited in that they only represent certain aspects of the system under study.

• **Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.**
MS-ESS1-2; MS-ESS2-6

ENERGY AND MATTER In grades 6-8, students learn that matter is conserved because atoms are conserved in physical and chemical processes. They also learn 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.

• **Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter**.
MS-ESS2-4

STRUCTURE AND FUNCTION[1]

STABILITY AND CHANGE In grades 6-8, students explain stability and change in natural or designed systems by examining changes over time and considering 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.

• **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.**
MS-ESS2-1
• **Stability might be disturbed either by sudden events or gradual changes that accumulate over time.**
MS-ESS3-5

[1] Crosscutting concept in grey (Structure and Function) is not cited in middle school Earth and Space Science.

Dr. Art's CCC Recommendations for Middle School Earth & Space Science

NOTE: Please read "Dr. Art's Overview Grade Span 6-8 CCC Recommendations" before reading the recommendation for this grade level.

NGSS in K-5 features a strong emphasis on both **Patterns** and **Cause and Effect**. These two CCCs work well together since humans are hard wired to perceive patterns in phenomena and to try to explain the patterns in terms of what might be causing them. In middle grades Earth and Space Science, students experience patterns and infer causal relationships in diverse contexts such as weather changes (MS-ESS2-5), regional climates (MS-ESS2-6), distribution of fossils and rocks (MS-ESS2-3), and motions in the sky of the Sun, Moon and stars (MS-ESS1-1).

A very important **Cause and Effect** CCC bullet states that "Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation." The only citation in Grades 6-8 for this bullet occurs in Earth & Space Science with respect to designing a method for monitoring and minimizing a human impact on the environment (MS-ESS3-3). Complex phenomena such as environmental impacts and changing weather conditions (MS-ESS2-5) have many features that may lead to mistakenly attributing causation to two events that are both happening at the same time but are not causing each other.

As described in Dr. Art's Overview 6-8 Grade Span, both testing and predicting can help distinguish between causation and correlation. With respect to prediction, the CCC bullet "Cause and effect relationships may be used to predict phenomena" is cited three times in MS Earth & Space Science. Another relevant cause/effect bullet (not cited in MS ESS) advises that "phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability." Students may expect cause and effect relationships to be "all or none," but this bullet can help them have more realistic expectations about the results from testing cause and effect relationships in complex systems. See also in the 6-8 Grade Span Overview the related discussion of how "mechanism" can provide evidence whether a relationship is causal or not.

With respect to the CCC of **Scale, Proportion, and Quantity**, the 6-8 Grade Span Overview explains why students need to experience the importance of scale considerations in multiple contexts and in each middle school grade level. In MS Earth & Space Science, students experience scale in at least three very different contexts: scale properties of objects in the solar system (MS-ESS1-3), evidence of geological time (MS-ESS1-4), and geoscience processes that change Earth's surface (MS-ESS2-2). The cited Scale bullet for all three of these examples states: "Time, space and energy phenomena can be observed at various scales using models to study systems that are too large or too small." As noted in the DCI for MS-ESS2-2, "The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years."

The 6-8 Grade Span Overview document recommends that in each middle school grade level students experience the CCC of **Systems and System Models** and also connect that CCC with at least one of the three other "systems thinking" CCCs. In MS Earth & Space Science, developing models is the cited Science and Engineering Practice for one third of the Performance Expectations. This modeling emphasis very appropriate given the size and age of planet Earth, the solar system, and the universe.

MS-ESS2-1 provides an excellent opportunity for students to combine their use of **Systems and System Models** with the CCC of **Energy and Matter** as they develop models to describe the cycling of Earth's materials and the flows of energy that drive this process. Both of these CCCs are also very appropriate to assist investigations and reasoning about the water cycle (MS-ESS2-4). Students develop a model of the water cycle guided by the Energy and Matter bullet stating that "the transfer of energy drives the motion and/or cycling of matter." Earth's cycles of matter are also examples of **Stability and Change**, the CCC cited for the cycling of Earth's geo materials (MS-ESS2-1), another Performance Expectation that involves developing a model that features flows of matter and energy.

Both the water cycle and the rock cycle are examples of a whole system property. As described in Dr. Art's Overview 6-8 Grade Span, the NGSS descriptions of systems do not sufficiently convey that systems have properties that are very different than those of their parts. NGSS does include that systems have *functions* that arise from the interactions of parts. While a function is an example of a whole system property, there are many kinds of whole system properties that are not system functions. A car has the whole system function of transportation. A car's fuel efficiency and carbon footprint are other whole system properties. Students in Integrated Grade 6 can investigate how the flows of carbon into and out of vehicles are changing Earth's whole system property of global climate (the CCC of **Stability and Change** of systems associated with MS-ESS3-5).

Note that the CCC of **Structure and Function** is not cited in MS Earth & Space Science. As described in the Overview document, function does not apply to Earth & Space Science contexts. It is much more appropriate when design is involved, whether it is the design of natural selection or human design in solving problems.

