Promoting K-12 Geoscience Education Through an Emphasis on Geoscience Practices and Crosscutting Concepts

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ABSTRACT

The Next Generation Science Standards (NGSS) are triggering an unprecedented change in U.S. science education, with the defining NGSS characteristic being is its 3-dimensional interweaving of science content with both science & engineering practices and a set of crosscutting concepts. The addition of the science and engineering practices (SEPs) and crosscutting concepts (CCCs) into the science standards of more than ¾ of U.S. schools will revolutionize how K-12 (and beyond) geoscience education is taught. The inclusion of the SEPs and CCCs into the standards of at least 41 states stands to significantly improve student understanding of all areas of science. Current educational research shows that allowing students to study a smaller volume of scientific content through deeper, active, practice-centered, problem-based, and phenomenon-based learning methods not only allows students to appreciate and enjoy science more, but also to retain and recall more scientific information than traditional memorization-centered methods. However, the benefits for geoscience education are enhanced both because of the opportunities provided by the SEPs and CCCs and because of the liabilities of previous standards. The SEPs have a strong emphasis on obtaining, analyzing, and interpreting data, and this benefits geoscience because of its strong data-driven observational nature. The SEPs and CCCs also include connections to STEM concepts relating to engineering, technology, and computation, and this favors geoscience because of its strong NGSS emphasis on human sustainability, reducing the risks from natural hazards, minimizing human impacts while obtaining natural resources, and reigning in global warming. The NGSS identifies certain performance expectations as having strong STEM connections, are there are more of these call-outs for high school geoscience than for life and physical science combined. The CCCs also have a strong emphasis on system processes, and this will help move geoscience education away from a dull set of classifications to a vibrant transdisciplinary interconnection of Earth Science Systems. Significant challenges lay ahead, such as developing assessments that can adequately monitor the impacts of the SEPs and CCCs, but geoscience education stands to greatly improve through their inclusion.

The NGSS Practices of Science and Engineering (SEPs)

1. Asking questions (*for science*) and defining problems (*for engineering*)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (*for science*) and designing solutions (*for engineering*)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The NGSS Crosscutting Concepts

1. Patterns
2. Cause and effect
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

NRC Framework: Three Dimensions of
(1) Disciplinary Core Ideas (DCIs)
(2) Science & Engineering Practices (SEPs)
(3) Crosscutting Concepts (CCCs)

A) DCIs = Encyclopedia
B) DCIs + CCCs = Textbook
C) SEPs = Random activities
D) SEPs + DCIs = Random science activities
E) SEPs + DCIs + CCCs = Coherent curriculum of **science and engineering practices**, connected to **disciplinary core ideas**, organized around **storylines of understanding** that build and apply ideas across time

Guiding Principles of the Crosscutting Concepts

1. The CCCs can help students better understand the Disciplinary Core Ideas (DCIs)

An intuitive understanding follows from seeing repetitions of structures, patterns, and processes, across different scientific systems

2. The CCCs can help students better understand the Science and Engineering Practices (SEPs)

For example, the CCC of "Systems and System Models" is clearly tied to the practice of "Developing and Using Models"

3. Repetition in different contexts is necessary to build familiarity

Repetition was avoided in the NGSS for PEs, SEPs, etc., but ***NOT*** for CCCs

4. The CCCs can provide a common vocabulary for science and engineering

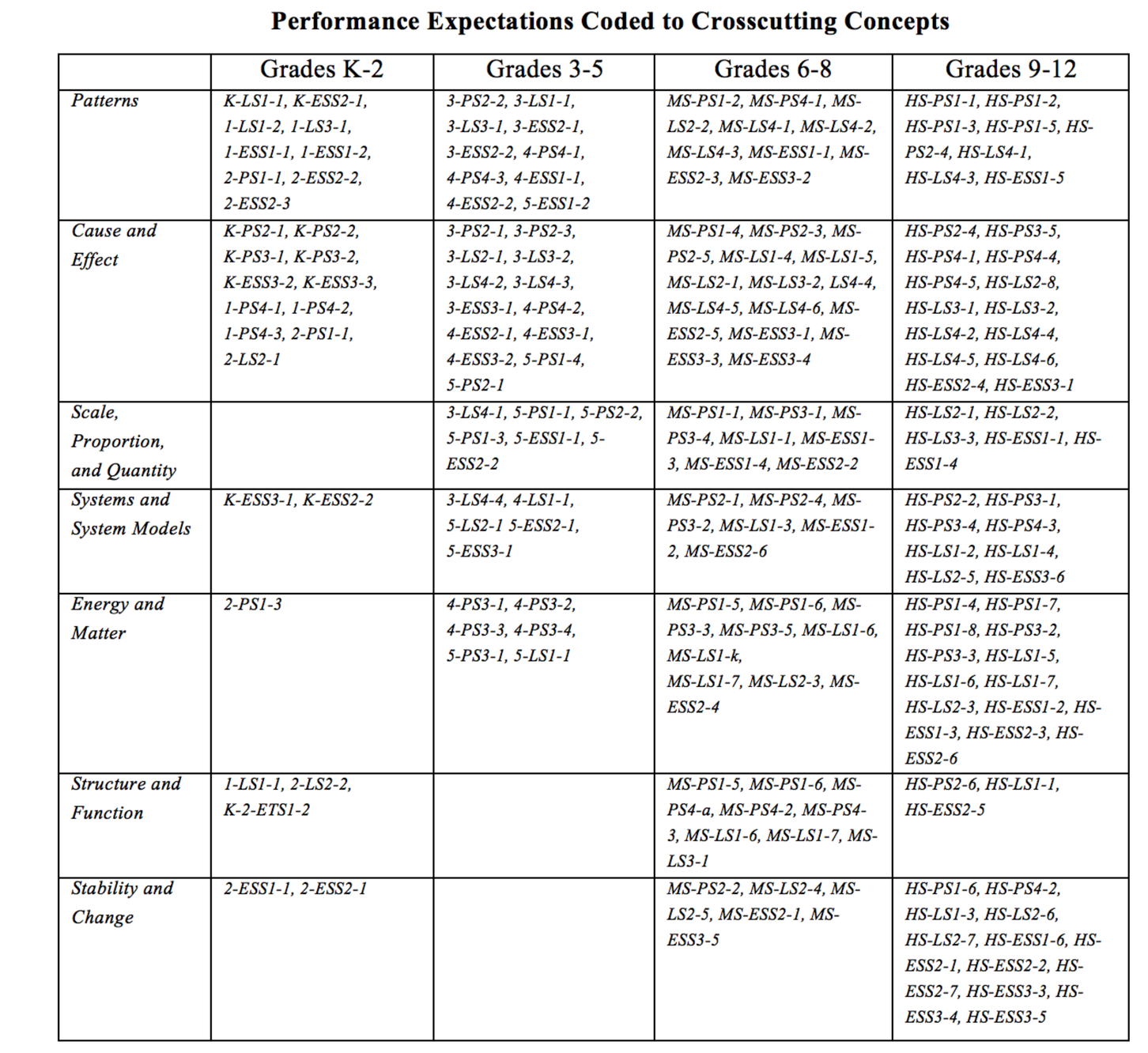
Can especially enhance understanding and engagement for:
a) English language learners,
b) students with language processing difficulties, and
c) students with limited literacy development

5. The CCCs should not be assesseed separately from practices or core ideas

For example, you would never have a lesson or module or assessment just on "PATTERNS" or "SYSTEMS"

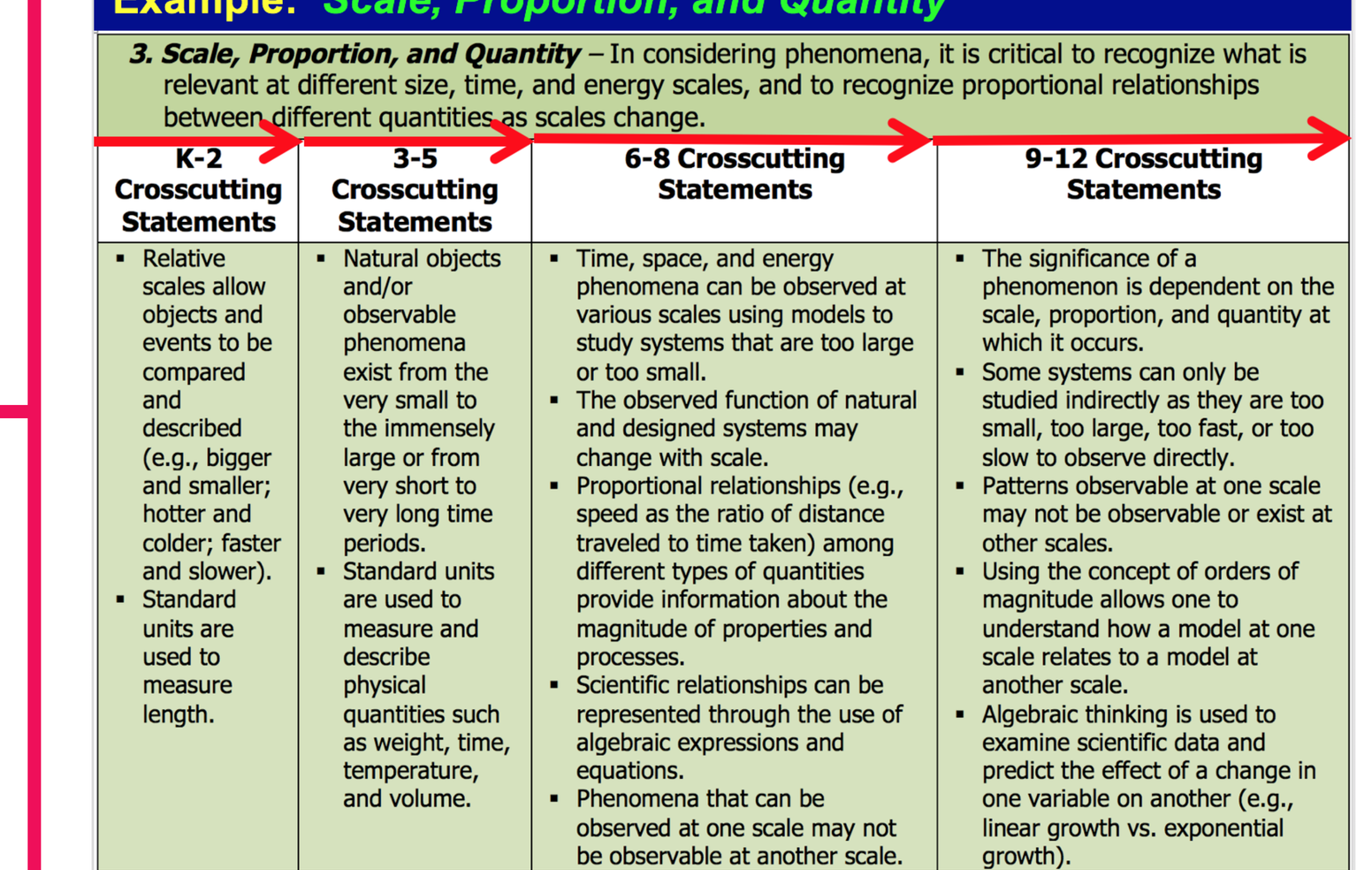
6. Students should address all seven CCCs over each of the K-5, 6-8, and 9-12 grade bands

Performance Expectations Coded to Crosscutting Concepts



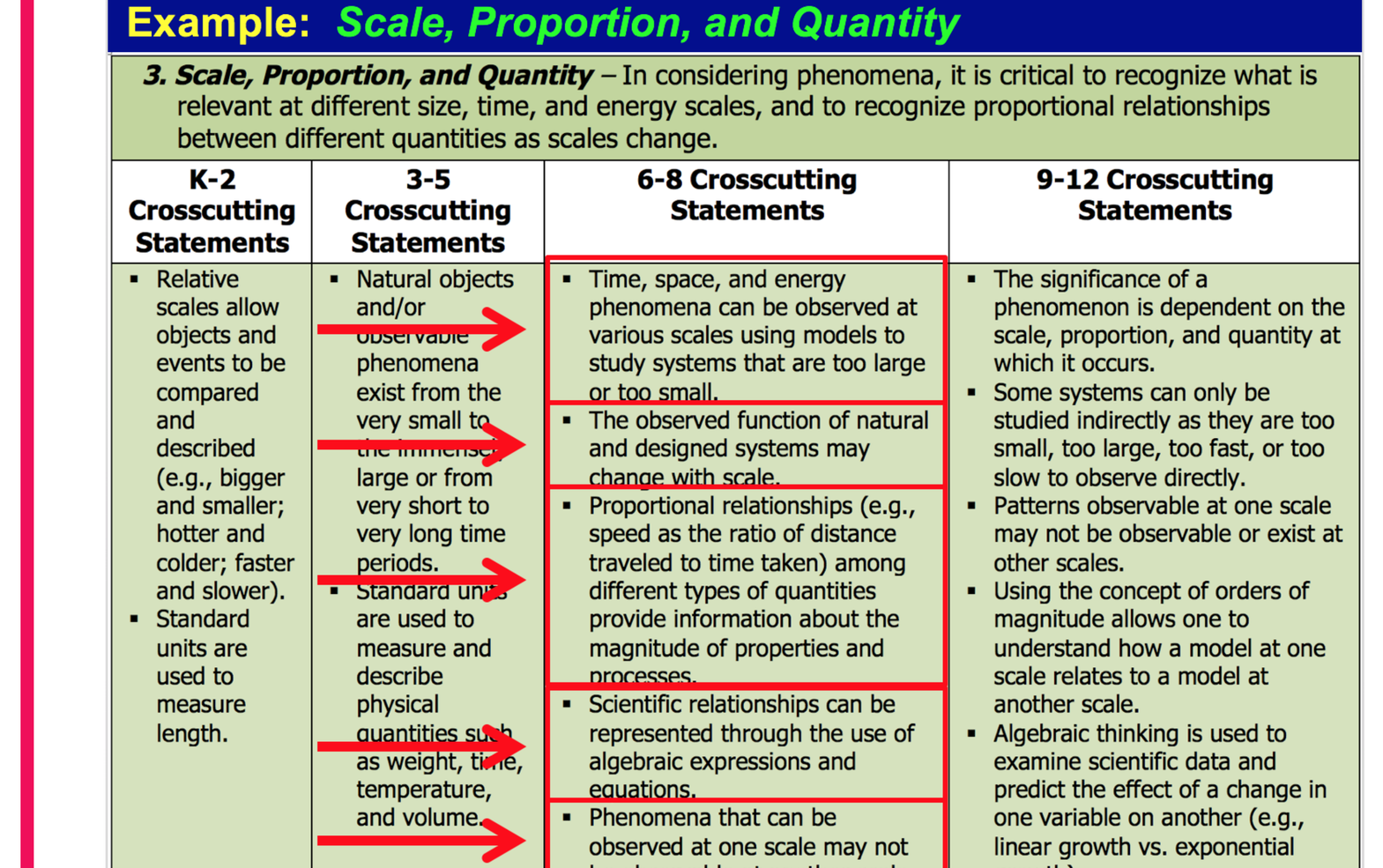
7. The CCCs grow in complexity and sophistication across the grades; curricular materials should only incorporate grade-appropriate elements

Example: *Scale, Proportion, and Quantity*



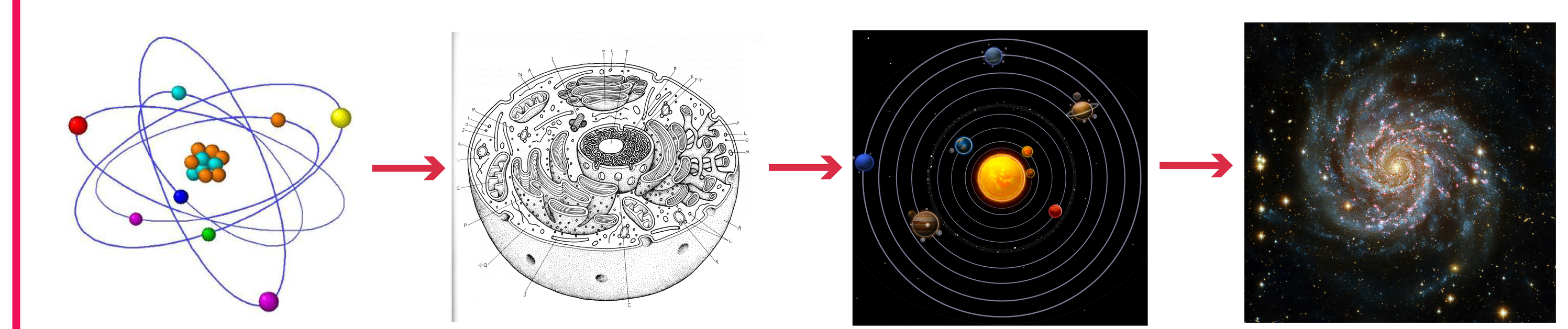
8. Performance expectations focus on some but not all capabilities associated with a CCC (i.e., students need only focus on one element of a CCC, not the full grade- or grade-band description)

Example: *Scale, Proportion, and Quantity*



9. The CCCs are interconnected -- they work together

SYSTEM STRUCTURE: Both "Patterns" and "Scale, Proportion, and Quantity" are ways of observing, categorizing, and classifying information, whether about physical objects or phenomena. Taken together, they provide a powerful tool for building understanding across multiple science domains.



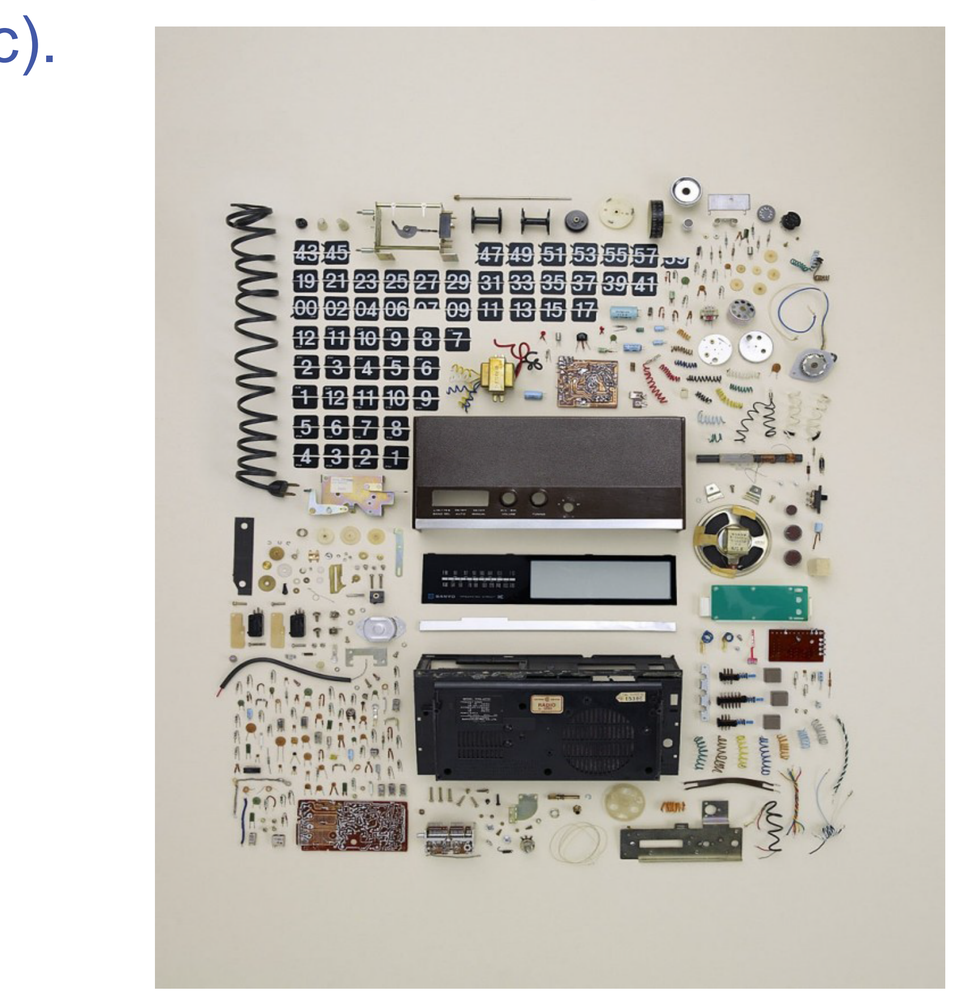
Common Groupings of the Crosscutting Concepts

1. System Structure:
- "Patterns"
- "Scale, Proportion, and Quantity"

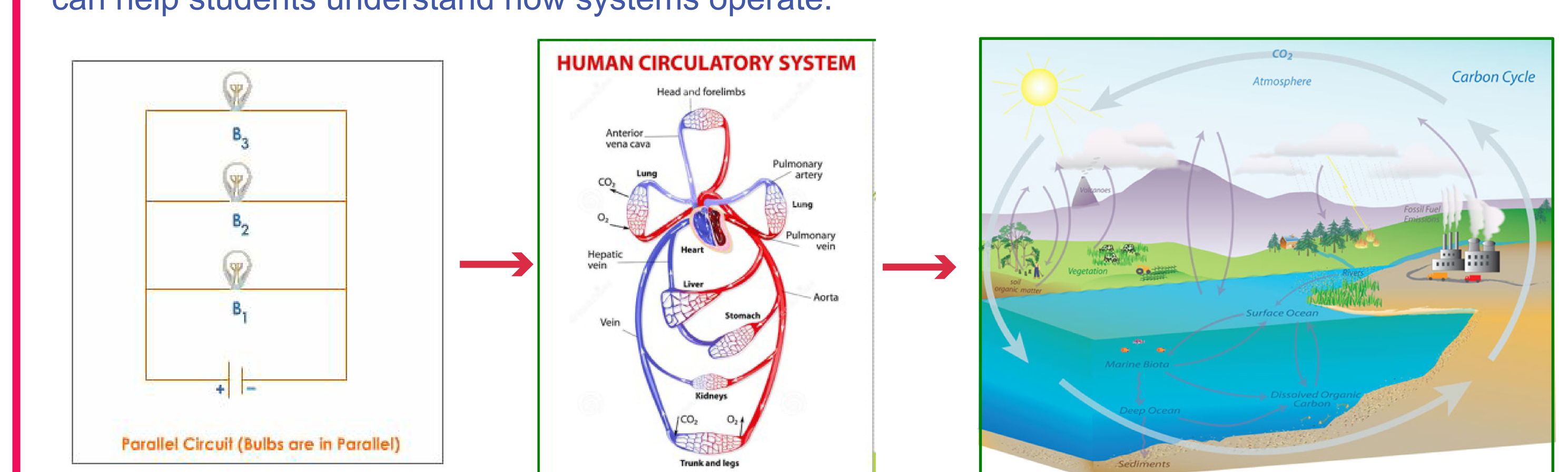
2. Component Structure:
- "Structure and Function"
- "Cause and Effect"

3. System Processes:
- "Systems and System Models"
- "Energy and Matter"
- "Stability and Change"

COMPONENT STRUCTURE: Together, "Structure and Function" and "Cause and Effect" can deconstruct a system down into its components. Unfortunately, this often does not allow students to see how the system operates (i.e., with this clock radio, you won't hear any music).



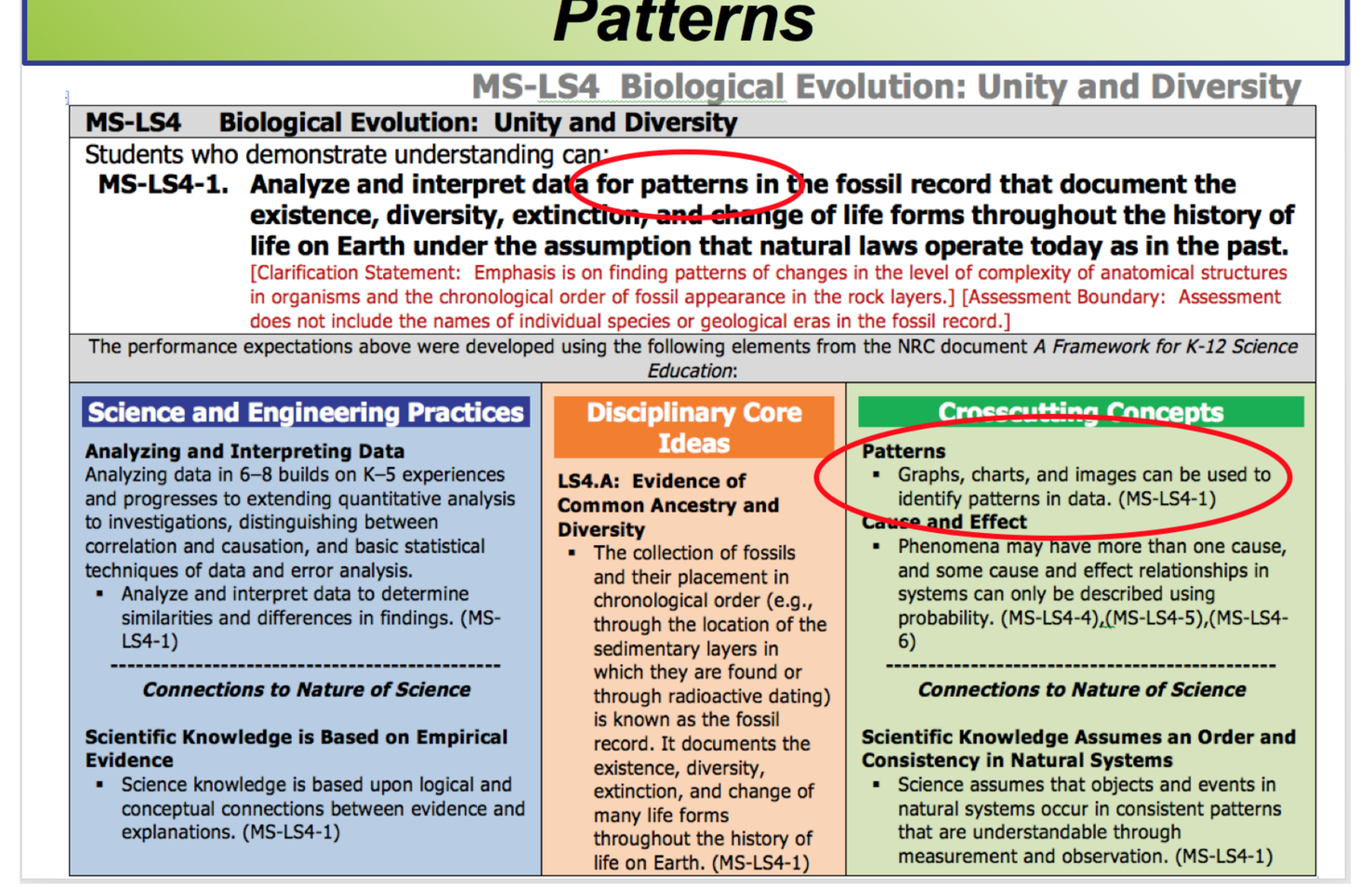
A holistic approach to science is exemplified by the crosscutting concepts of "Systems and System Models," "Energy and Matter," and "Stability and Change." These all deal with understanding different aspects of nature by examining how components of a system function together. Taken together, they can help students understand how systems operate.

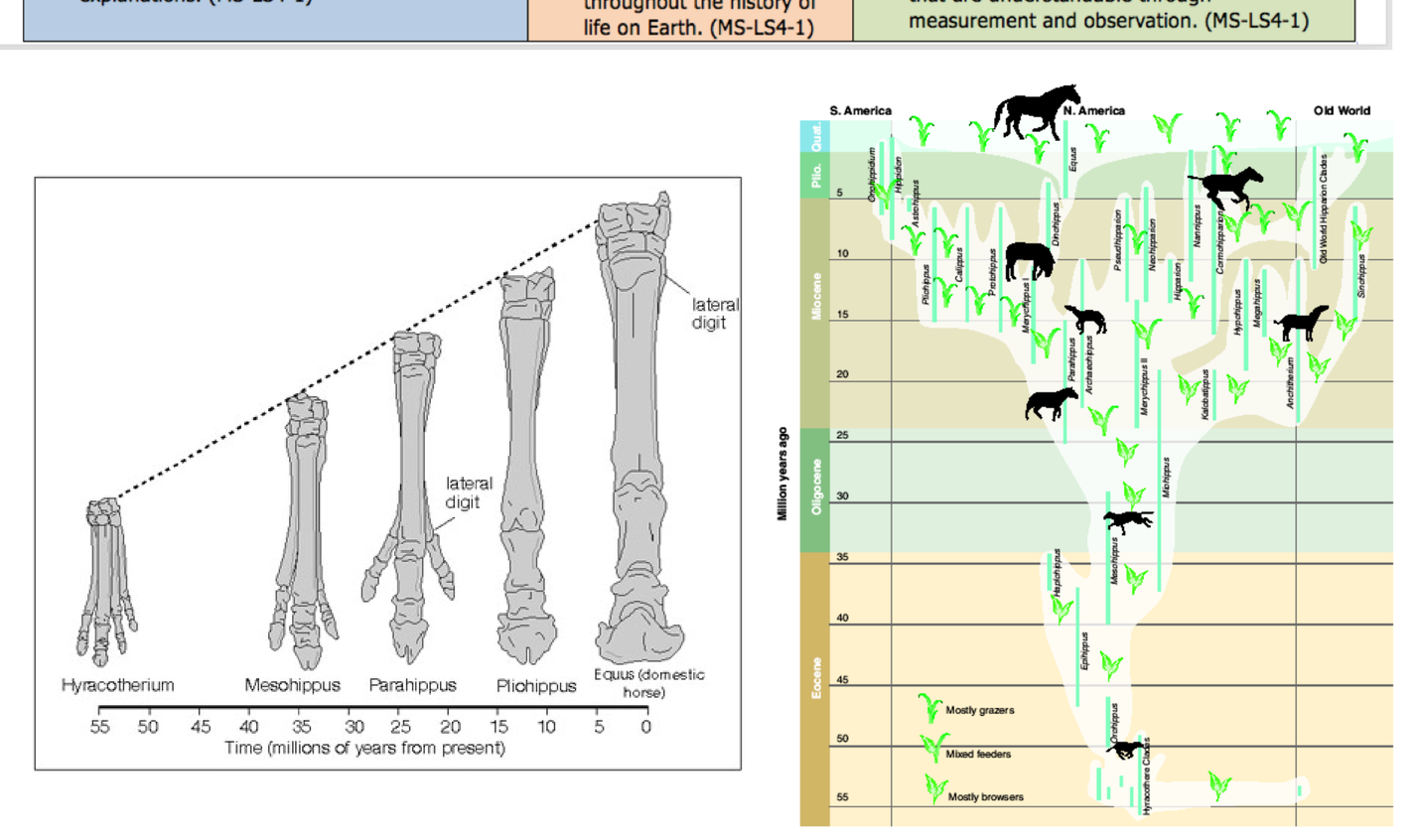


ESS CCC Examples

Crosscutting Concepts: ***Patterns***

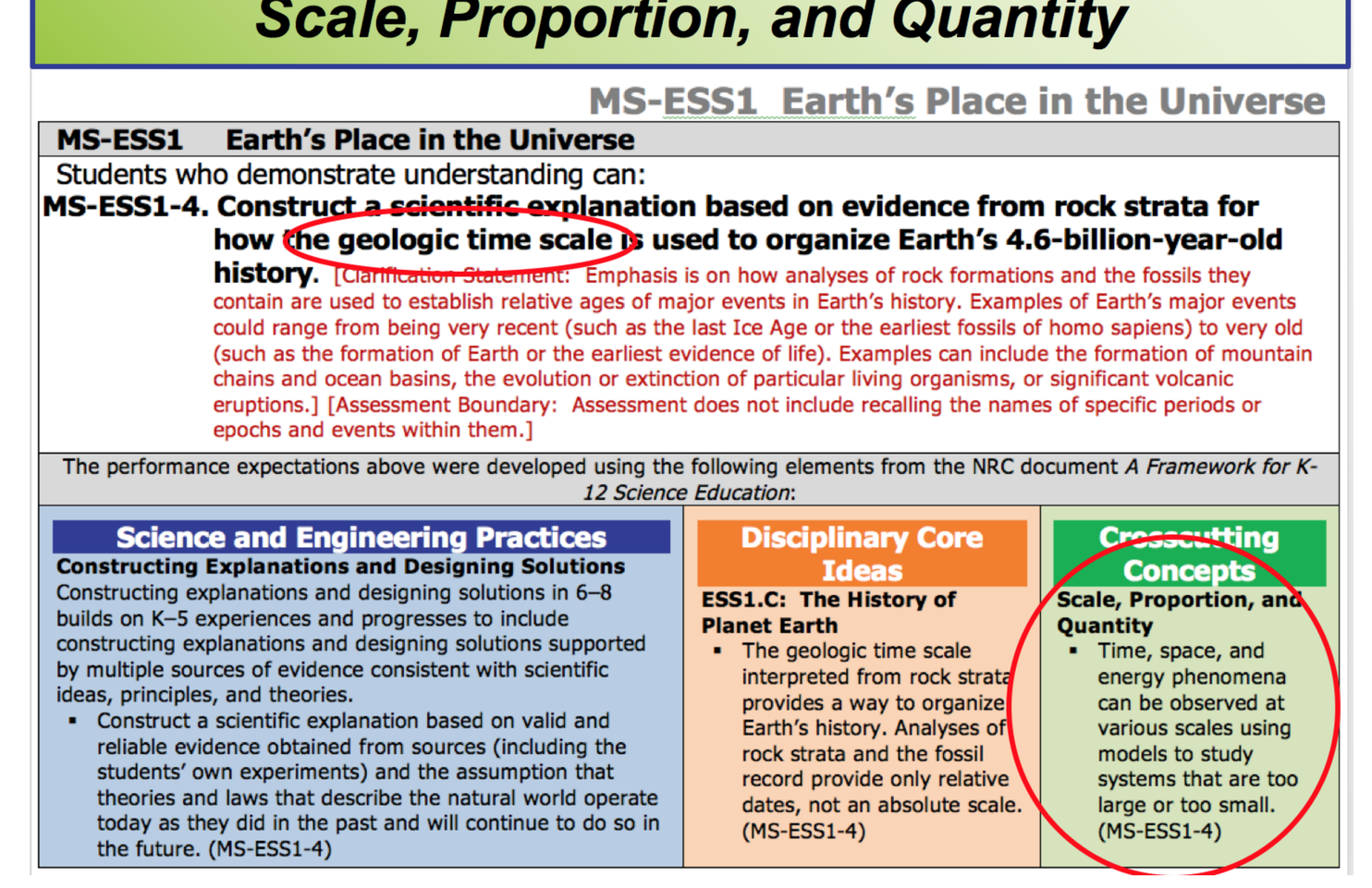
MS-LS4 Biological Evolution: Unity and Diversity

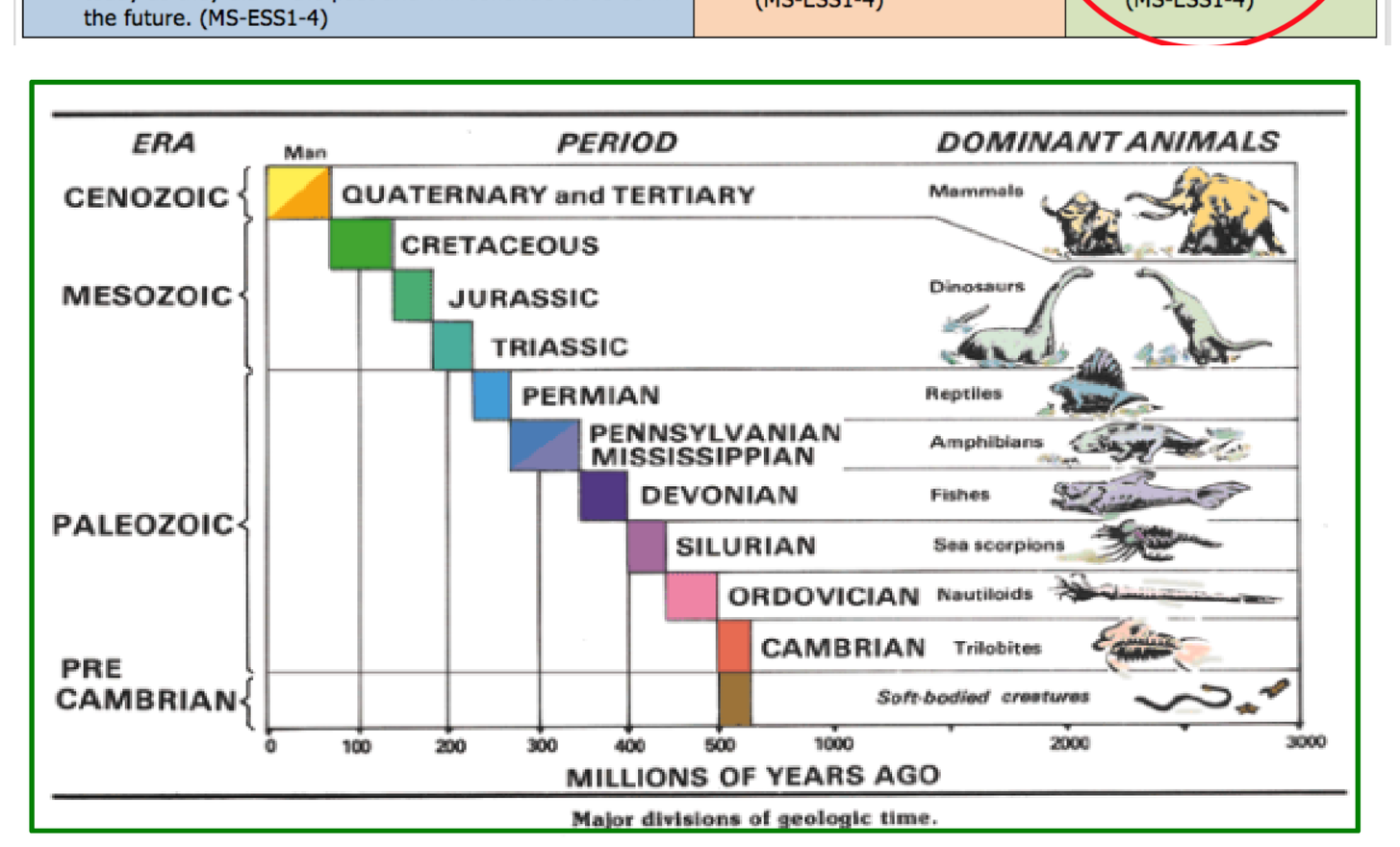




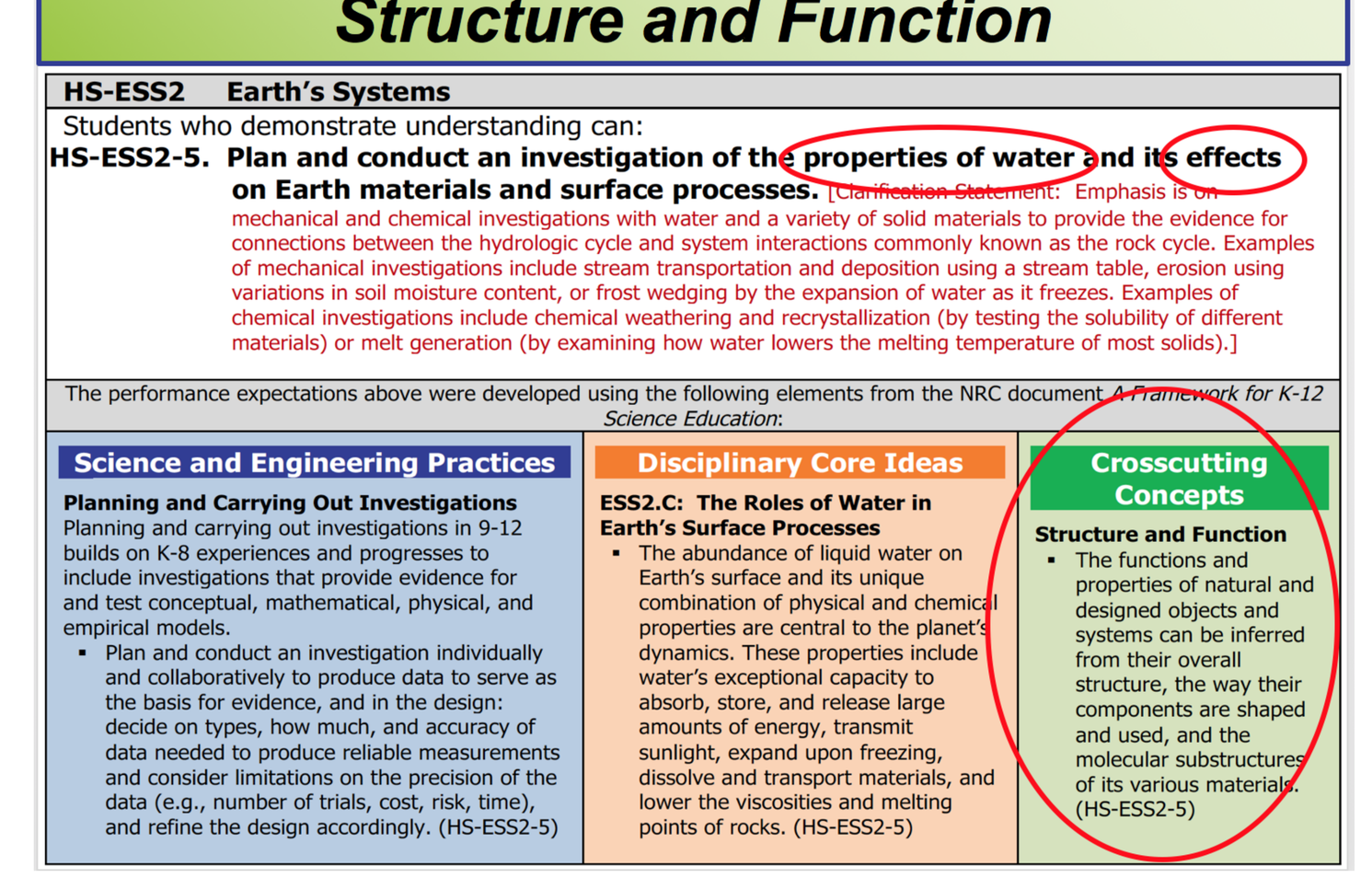
Crosscutting Concepts: ***Scale, Proportion, and Quantity***

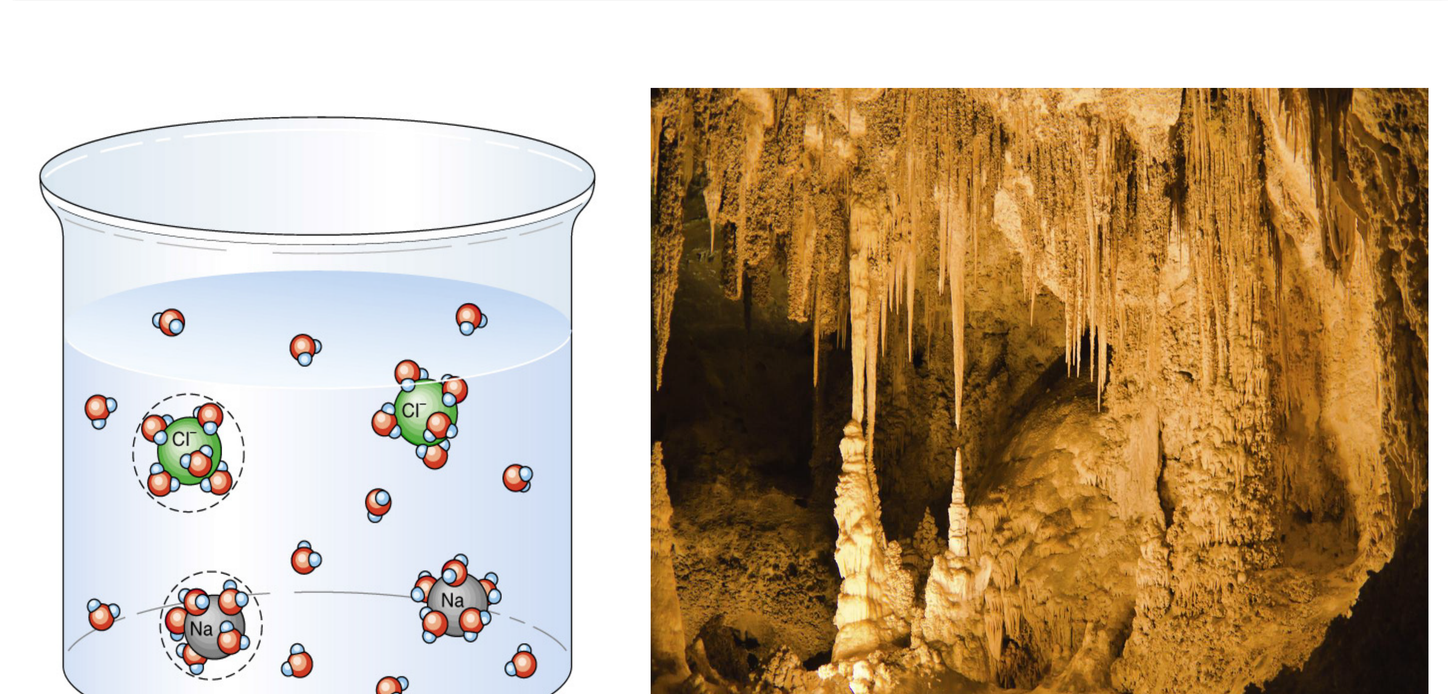
MS-ESS1 Earth's Place in the Universe





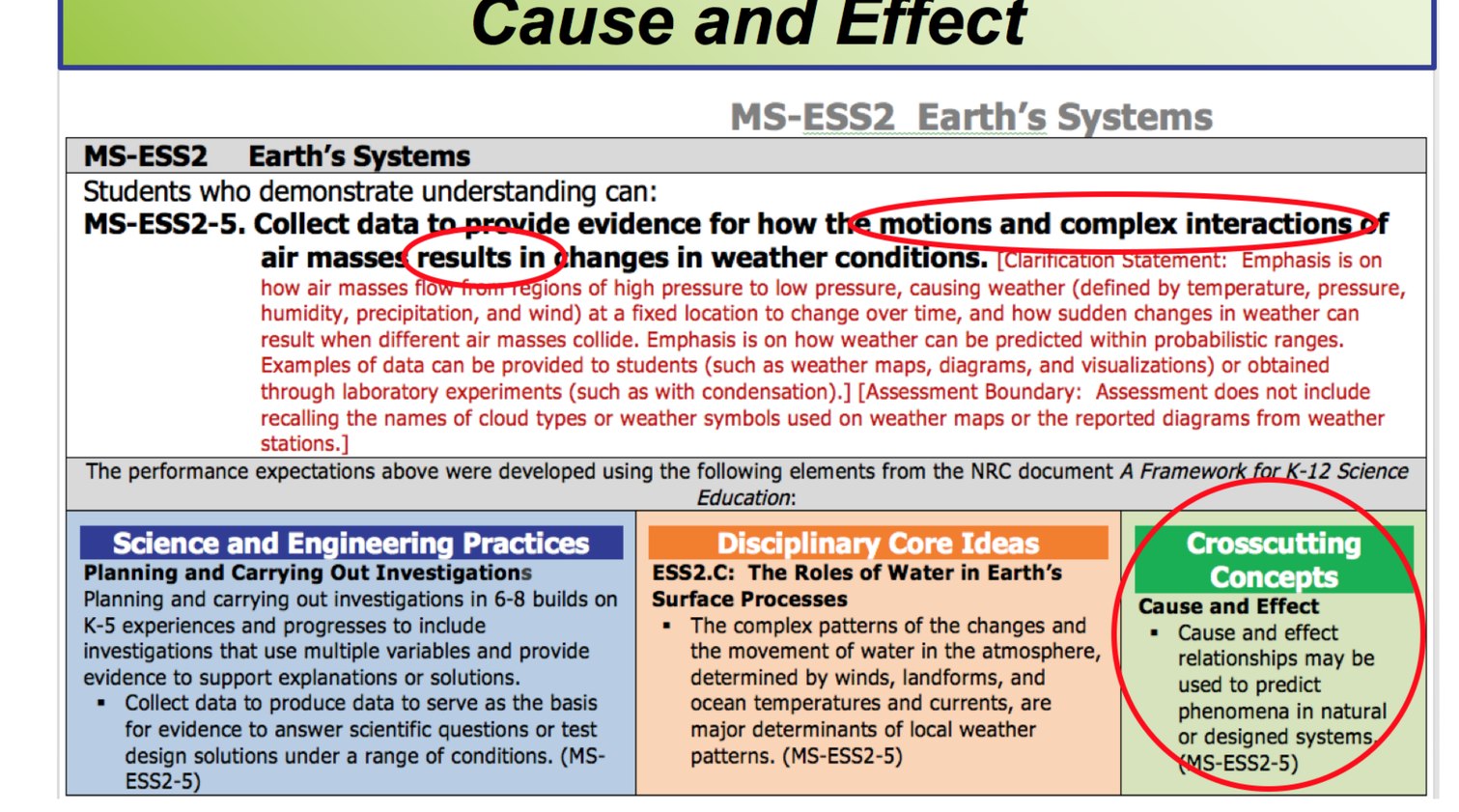
Crosscutting Concepts: ***Structure and Function***

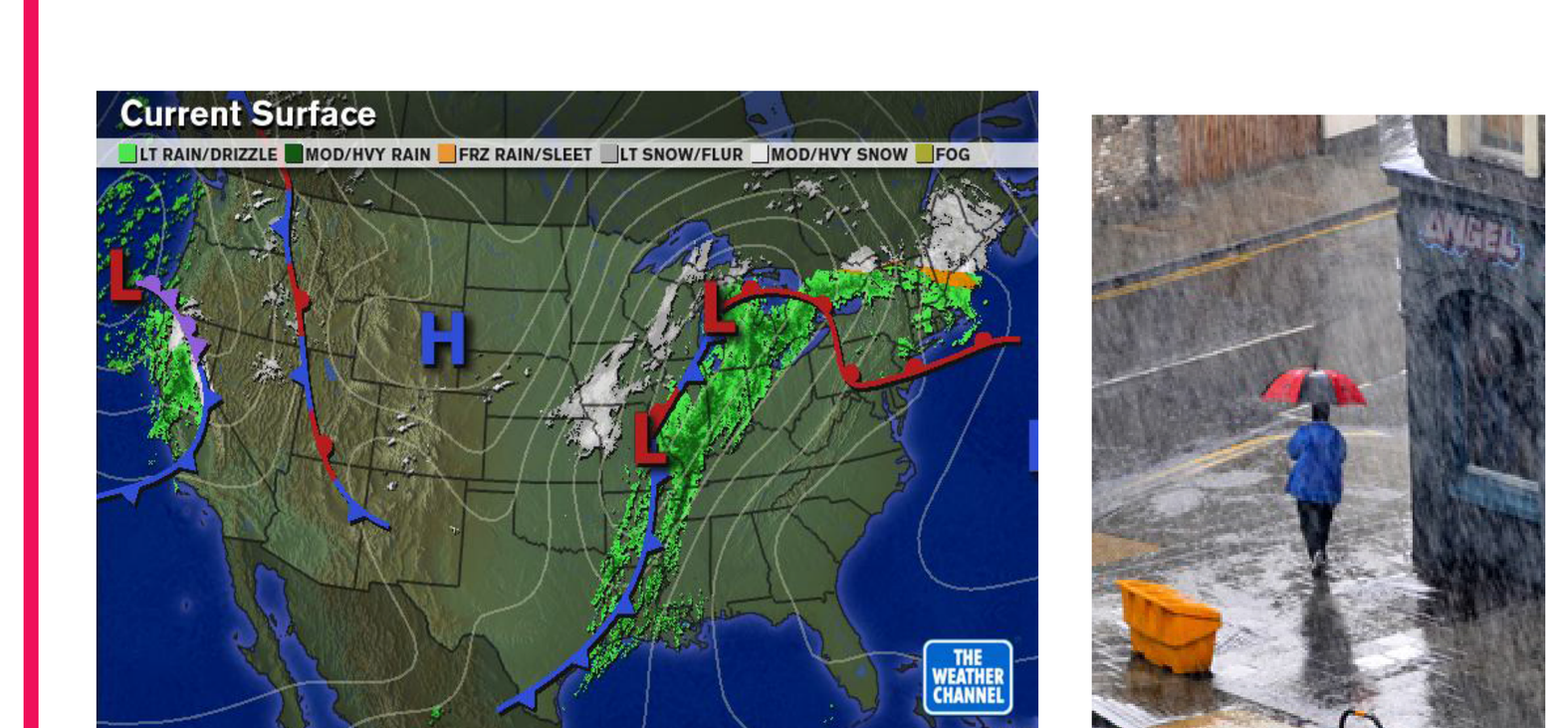




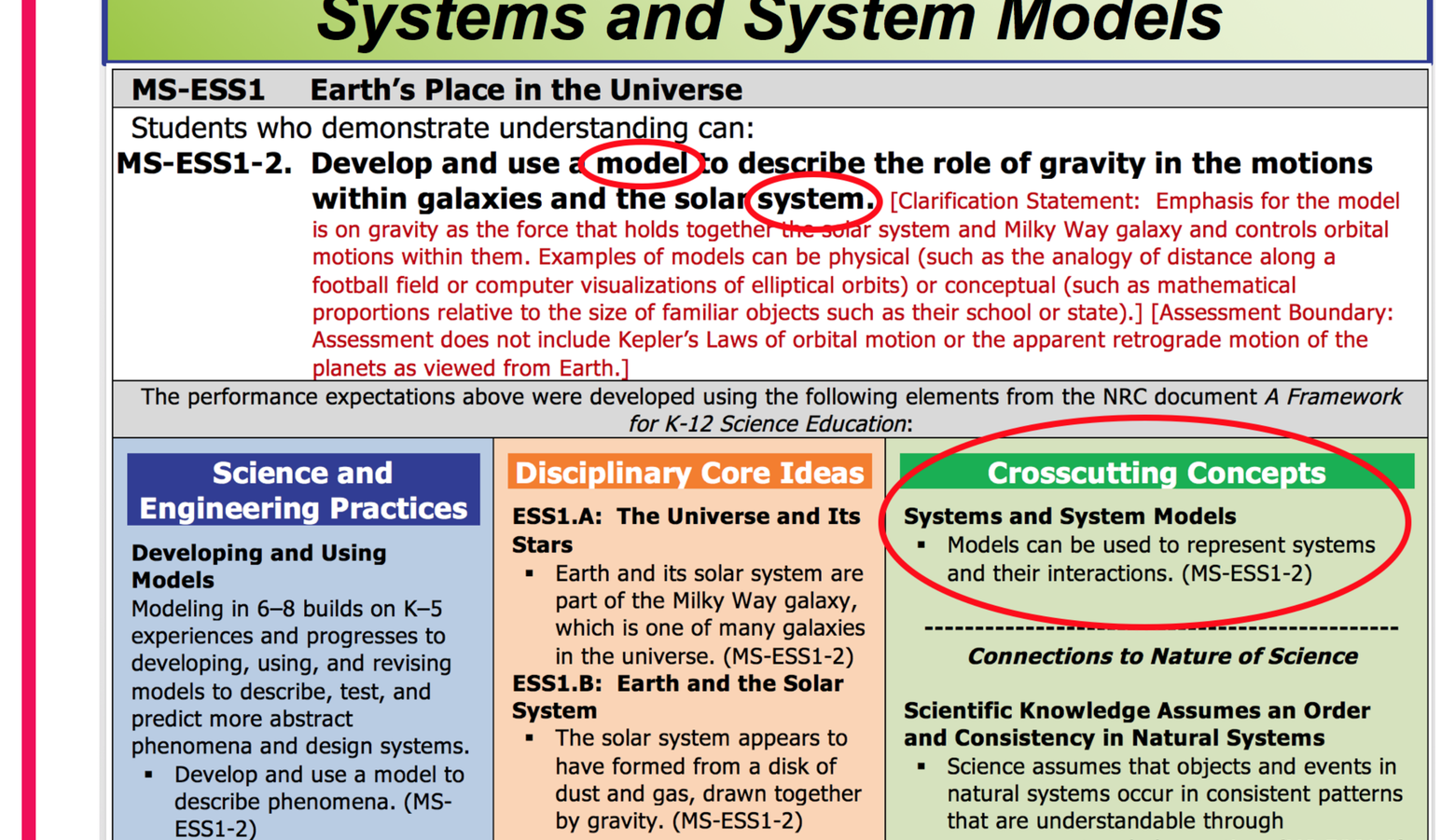
Crosscutting Concepts: ***Cause and Effect***

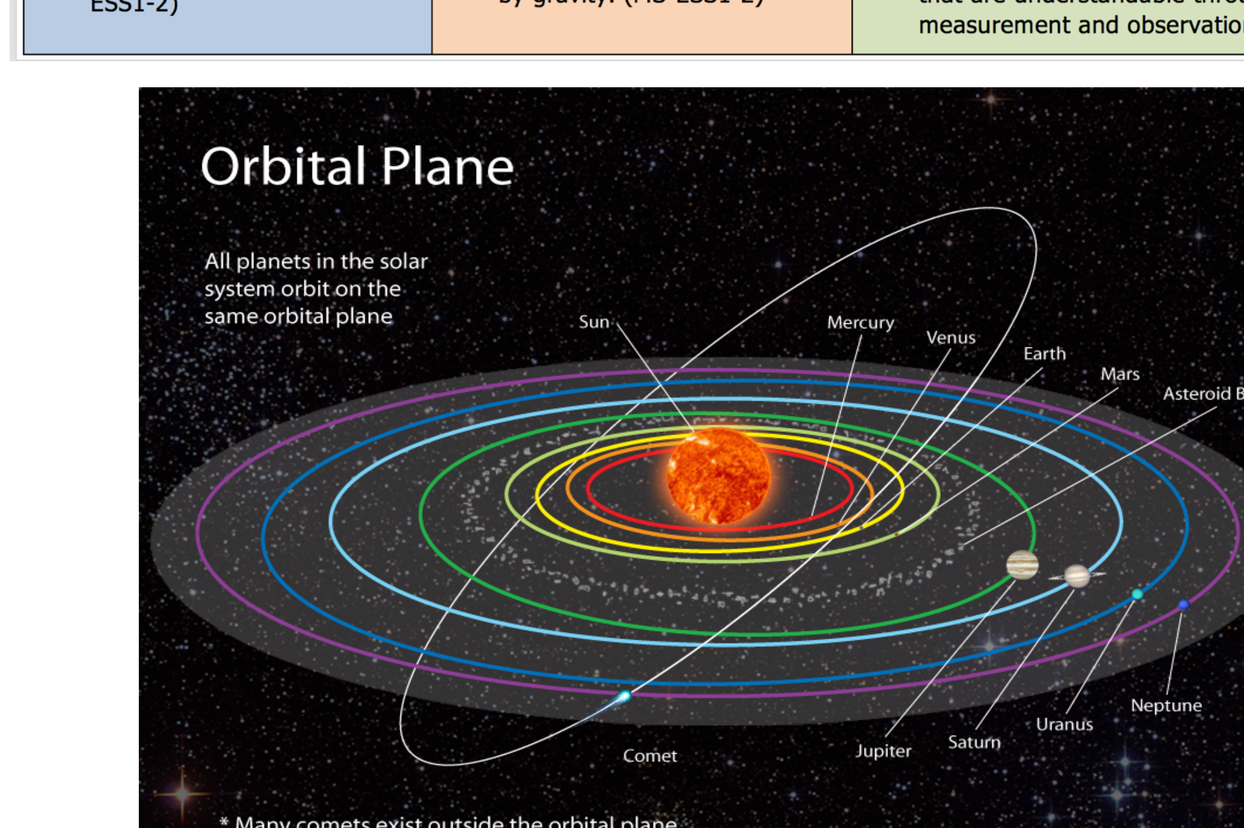
MS-ESS2 Earth's Systems





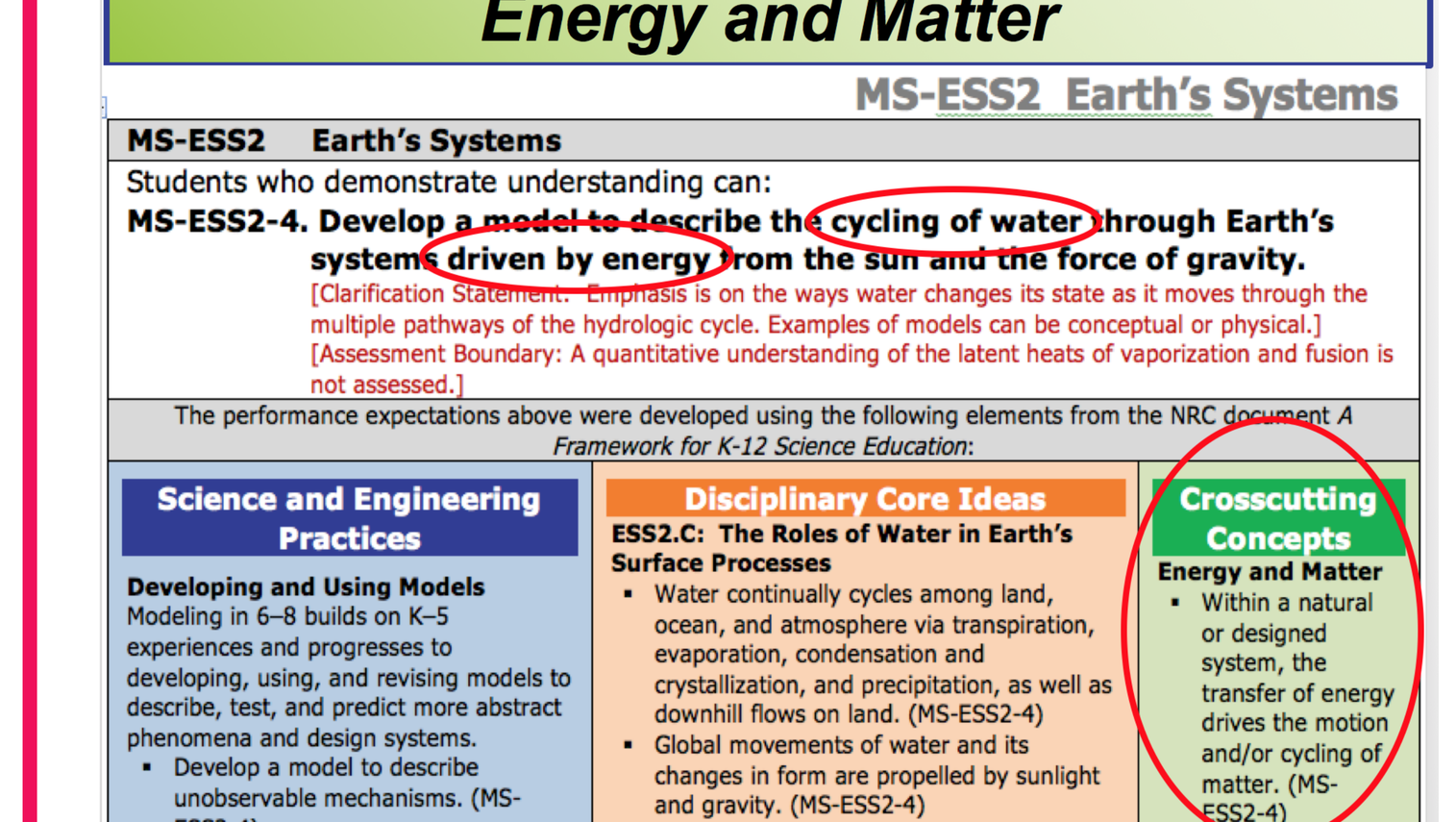
Crosscutting Concepts: ***Systems and System Models***

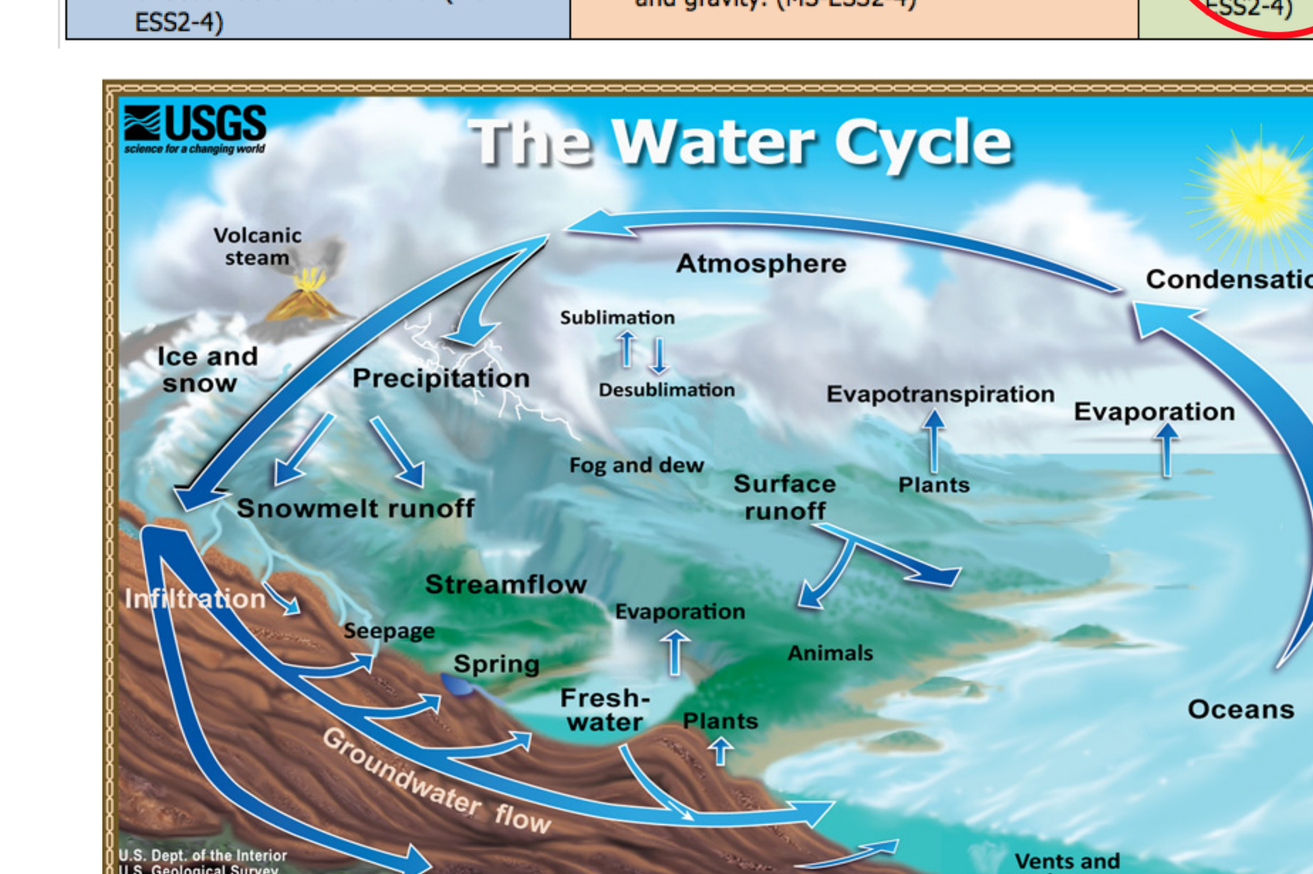




Crosscutting Concepts: ***Energy and Matter***

MS-ESS2 Earth's Systems





Crosscutting Concepts: ***Stability and Change***