The Role of Crosscutting Concepts in Student Science Performances

From Principles to Practice:
Utah Science and Engineering Education Standards Conference

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Partnership for Effective Science Teaching and Learning

Overview

- History of Crosscutting Concepts in Science Education standards
- Role of Crosscutting Concepts in Science Performances
- Utility of Crosscutting Concepts
- NRC Framework for K-12 Science Education
  - Keys to the Vision for Science Education
  - Crosscutting Concepts
- Science Performance
- Focus of Instructional Engagement
- Discussion

Common Themes, Unifying Concepts, and Crosscutting Content

- **Four Common Themes in the AAAS Benchmarks for Science Literacy (1995) –** 1) systems, 2) scale, 3) change and constancy, and 4) models

- **Five Unifying Concepts in the National Science Education Standards (1996) –** 1) systems, order, and organization, 2) evidence, models, and explanation, 3) change, constancy, and measurement, 4) Evolution and equilibrium, 5) form and function

- **Crosscutting Content in the NAEP 2009 Science Framework –** Crosscutting content are described conceptually and appear throughout the NAEP Framework. Examples include: *Energy Sources and Transfer in Physical Science; Uses, Transformations, and Conservation of Energy in Life Science; and Biogeochemical Cycles in Earth and Space Sciences, the theory of plate tectonics and the evolution of Earth's surface are inextricably linked with environmental pressures (such as geographic barriers), speciation, and the evolution of life. Such examples illustrate opportunities for assessing specific content in greater depth.*

Crosscutting Concepts in NRC Framework for K-12 Science Education

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

How are Crosscutting Concepts Different in NRC Framework?

- Crosscutting concepts are explicit within the Performance Expectations
- Crosscutting Concepts are described in detail in the Framework
- Crosscutting Concepts are described as a progression across grade-bands
- Science Performances include the crosscutting concepts as an integral part of students practices in terms of evidence to support explanations, gather information (observation), and develop arguments
- Matter and energy are included as Crosscutting Concepts as well as Core Ideas

Structure/Dimensions of the *Framework*

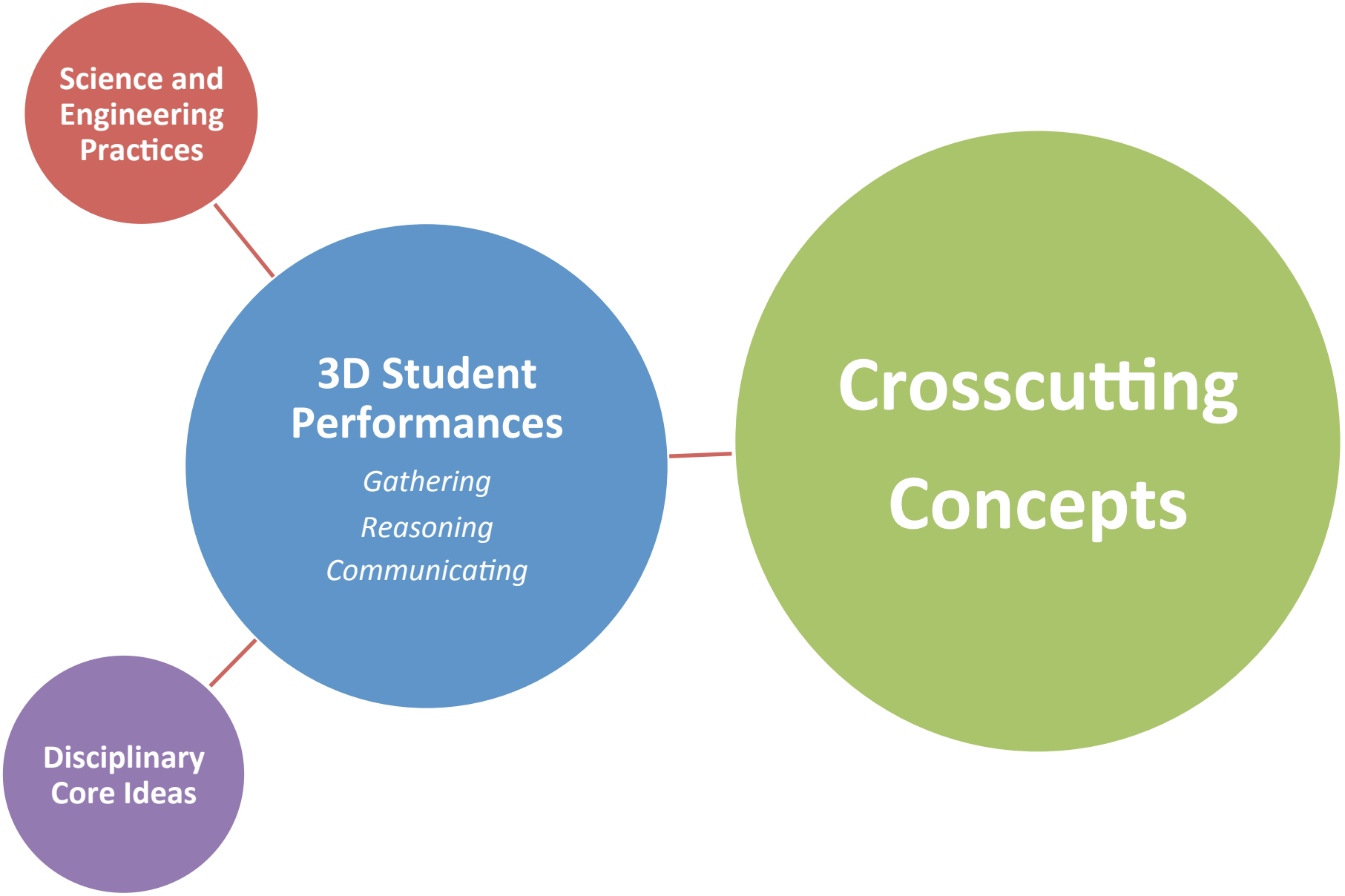
- Science and Engineering **Practices**
- Crosscutting **Concepts**
- Disciplinary Core **Ideas**

"The three dimensions of the Framework, which constitute the major conclusions of this report, are presented in separate chapters. However, in order to facilitate students' learning, the dimensions must be woven together in standards, curricula, instruction, and assessments.

When they explore particular disciplinary ideas from Dimension 3, students will do so by engaging in practices articulated in Dimension 1 and should be helped to make connections to the crosscutting concepts in Dimension 2."

NRC Framework Pages 29 - 30

3-D Model = Science Performance at the Intersection



How are Crosscutting Concepts Used?

- Crosscutting concepts help provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world.
- Crosscutting concepts contribute to sense making of novel phenomena.
- The *Framework* describes seven crosscutting concepts that support understanding of the natural sciences and engineering.
- The crosscutting concepts, when made explicit for students, contribute to their understanding of a coherent in a scientifically-based view of the world.
- Crosscutting concepts have utility for instruction.

Framework Pages 83-84

Crosscutting Concepts and Instruction

- Although crosscutting concepts are fundamental to an understanding of science and engineering, students have often been expected to build such knowledge without any explicit instructional support. Hence the purpose of highlighting them as Dimension 2 of the *Framework* is to elevate their role in the development of standards, curricula, instruction, and assessments. Crosscutting concepts should become common and familiar touchstones across the disciplines and grade levels. Explicit reference to the concepts, as well as their emergence in multiple disciplinary contexts, can help students develop a cumulative, coherent, and usable understanding of science and engineering.

Framework Page 83

Crosscutting Concepts

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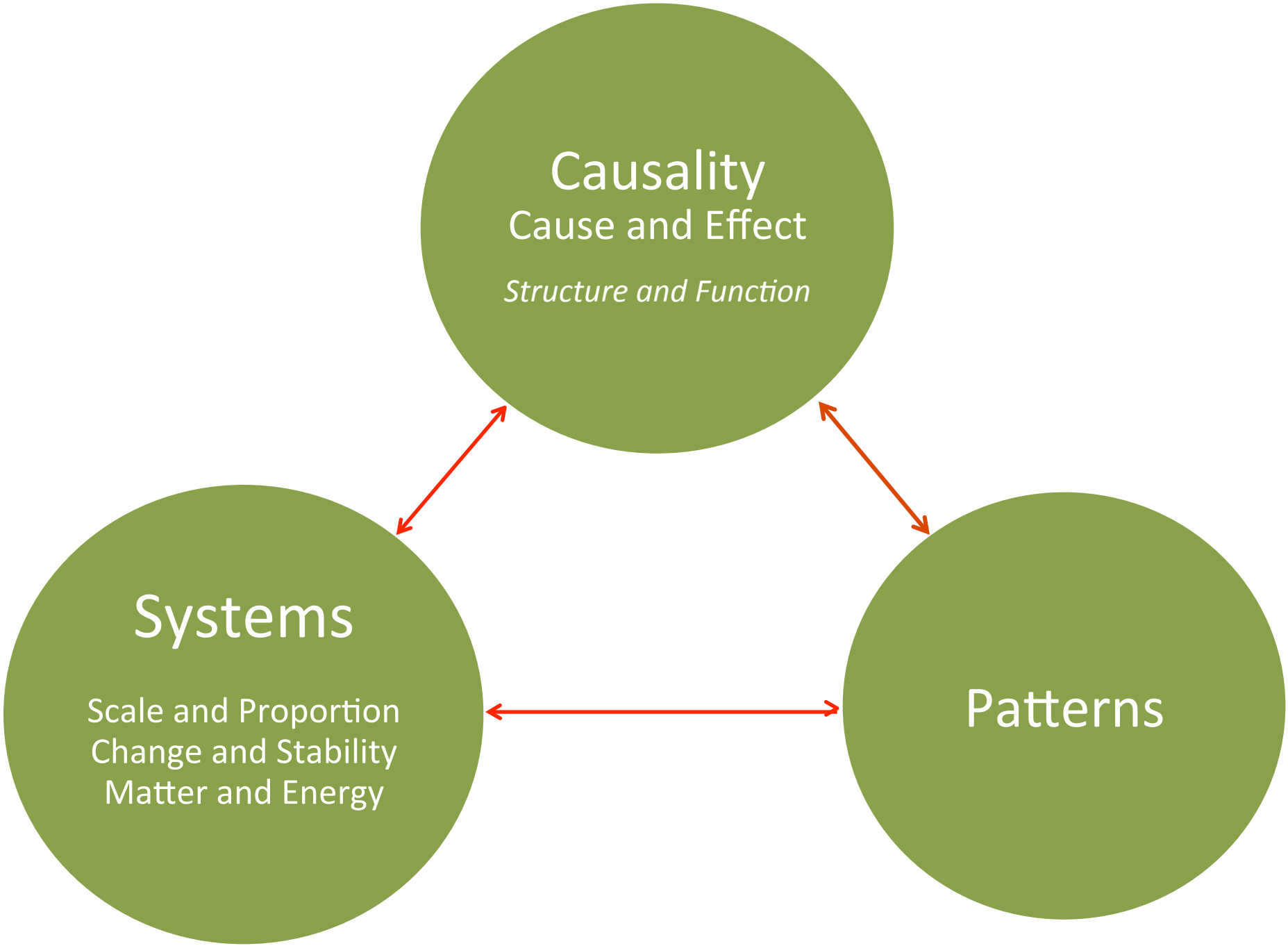

Causality
Cause and Effect
Structure and Function
Systems
Scale and Proportion
Change and Stability
Matter and Energy
Patterns

1. Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them

2. Cause and effect: *Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

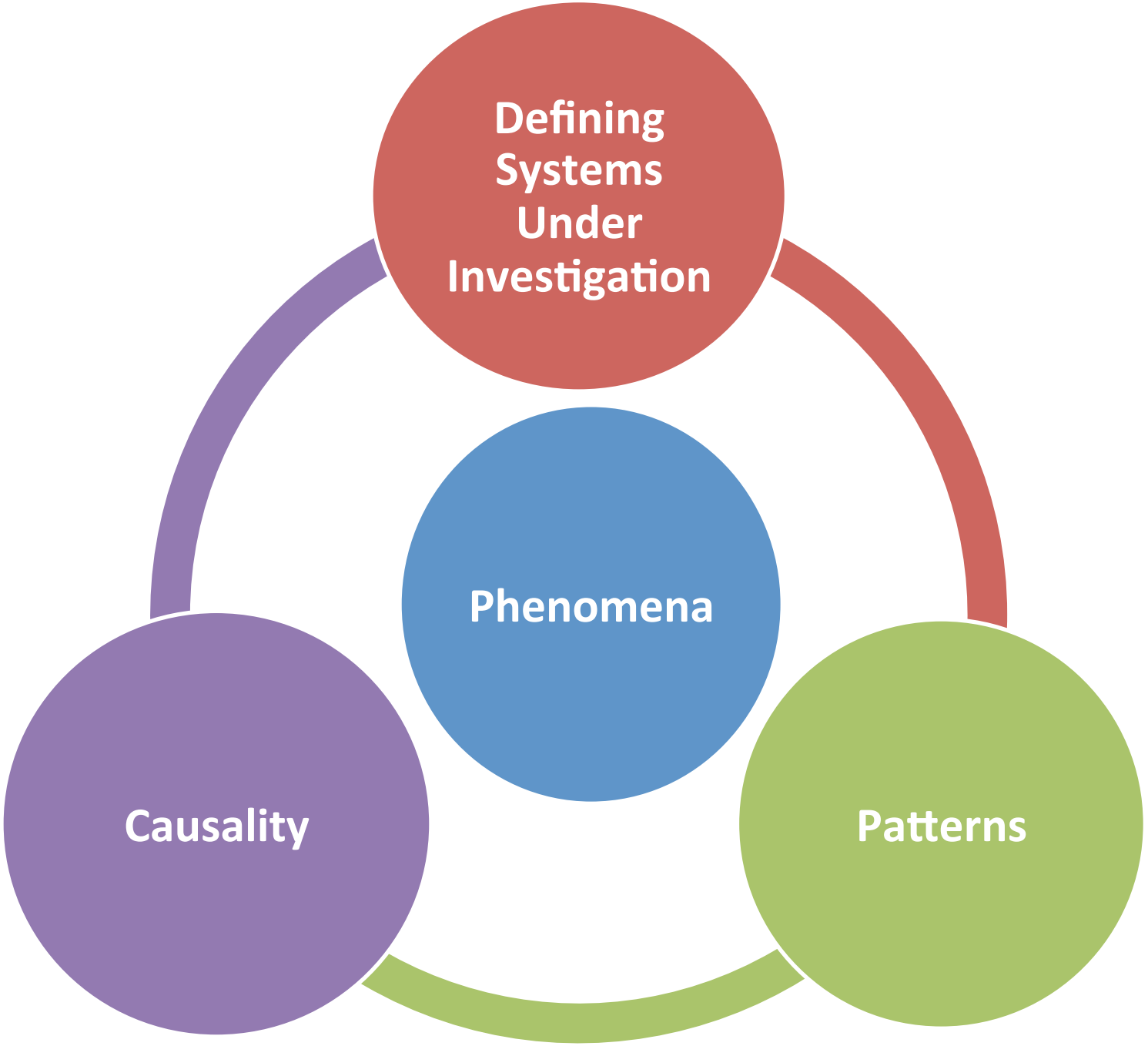
3. ***Scale, proportion, and quantity.*** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a **system's** structure or performance.

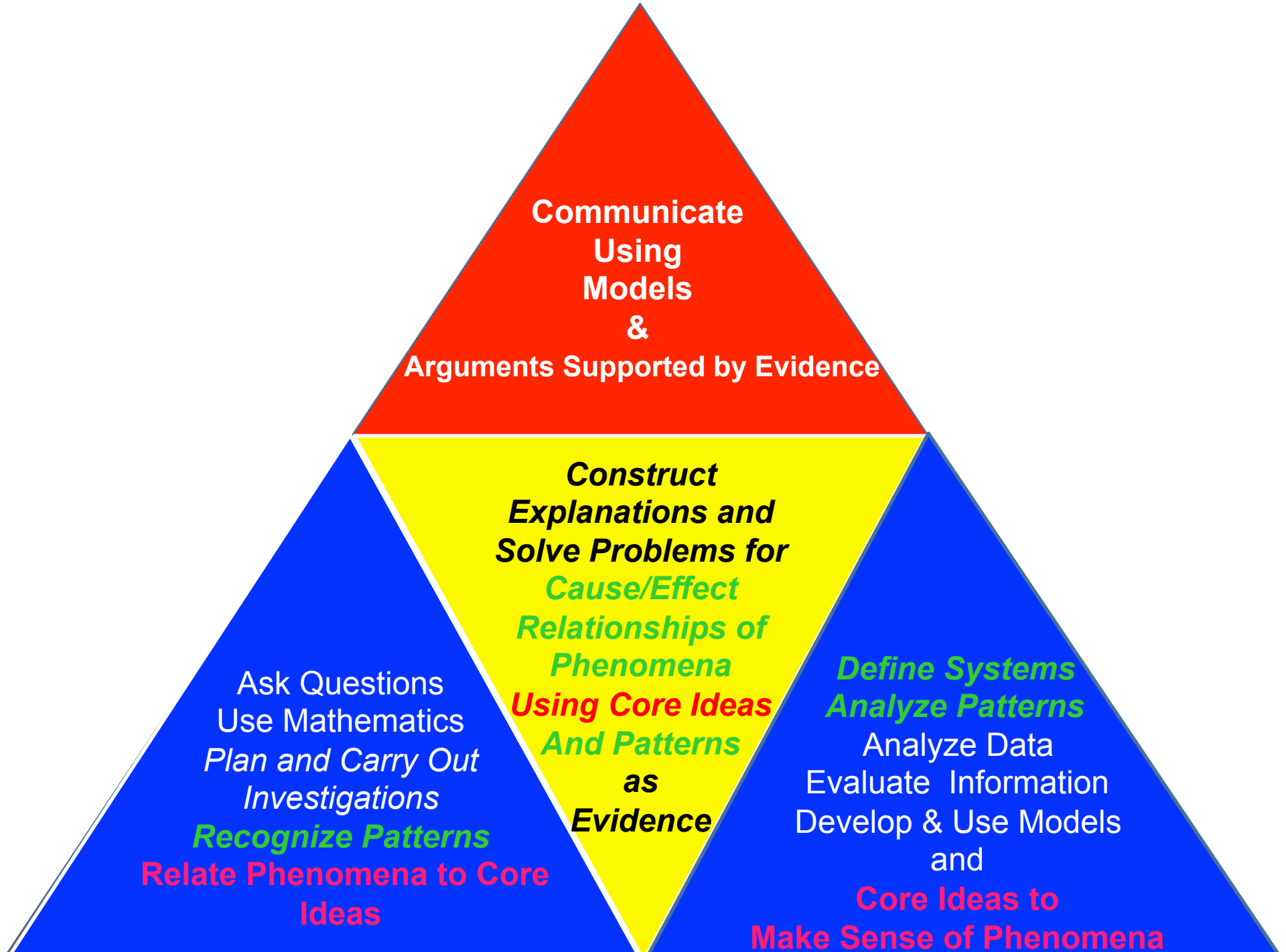
4. ***Systems and system models.*** Defining the system under study—specifying its boundaries and making explicit a model of that **system**—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

5. ***Energy and matter: Flows, cycles, and conservation.*** Tracking fluxes of energy and matter into, out of, and within **systems** helps one understand the **systems'** possibilities and limitations.

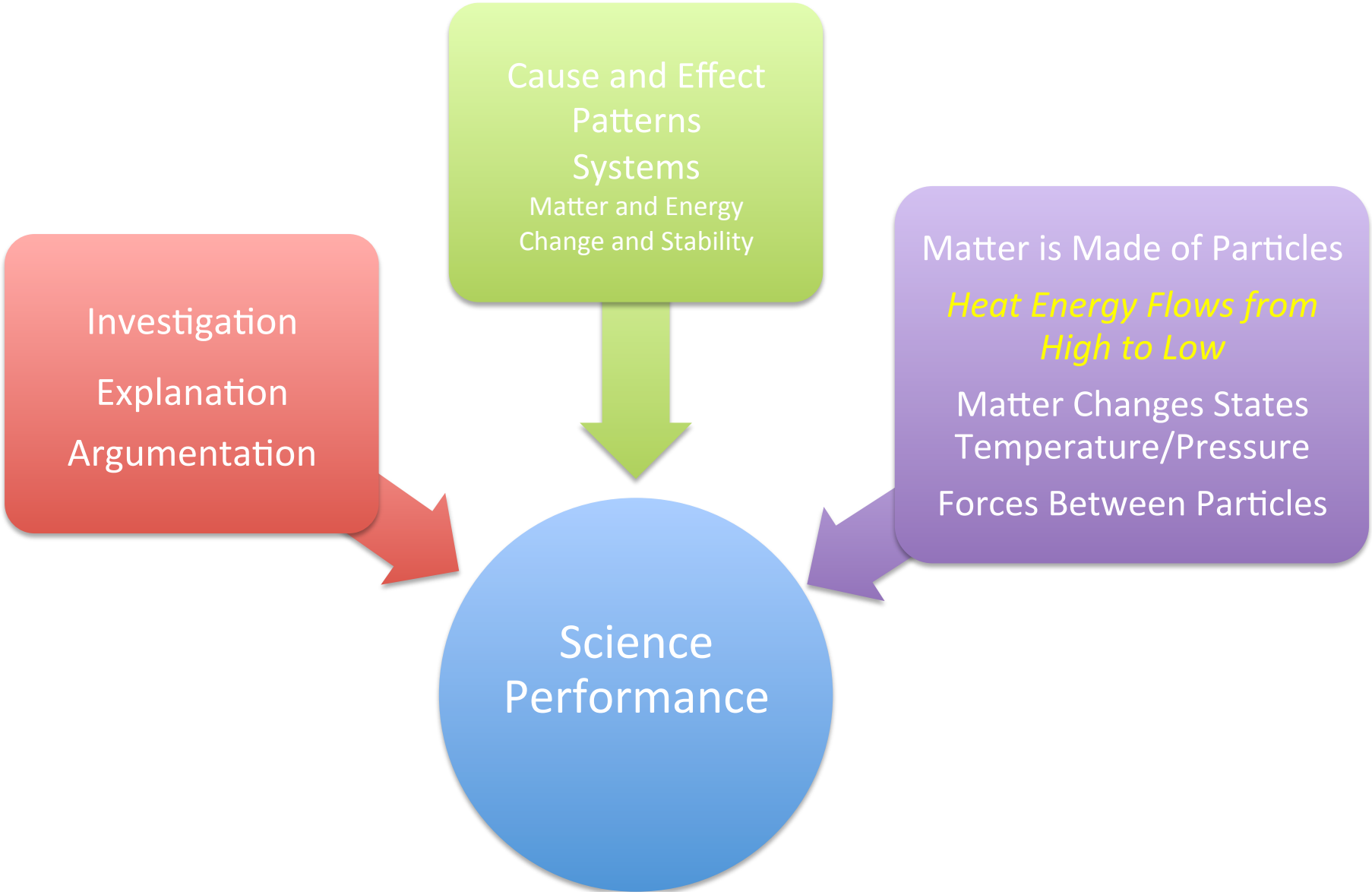
6. ***Structure and function.*** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. ***Stability and change.*** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a **system** are critical elements of study.


Defining Systems Under Investigation
Phenomena
Causality
Patterns


Communicate
Using
Models
&
Arguments Supported by Evidence
Construct
Explanations and
Solve Problems for
Cause/Effect
Relationships of
Phenomena
Using Core Ideas
And Patterns
as
Evidence
Ask Questions
Use Mathematics
Plan and Carry Out
Investigations
Recognize Patterns
Relate Phenomena to Core
Ideas
Define Systems
Analyze Patterns
Analyze Data
Evaluate Information
Develop & Use Models
and
Core Ideas to
Make Sense of Phenomena

Performance – Water Condensing on Bottle



Patterns in Clouds

Pattern?

Real Patterns Not Pareidolia

- **Pareidolia -** *the imagined perception of a pattern or meaning where it does not actually exist, as in considering the moon to have human features.*
- **Pareidolia** *(Noun)* **-** The tendency to interpret a vague stimulus as something known to the observer, such as interpreting marks on Mars as canals, seeing shapes in clouds, or hearing hidden messages in reversed music.

Pattern

Science Performance – Patterns in Clouds

Group Performance

1. Gather information about the formation and appearance of clouds.
2. Define the system and formulate questions about the causes of patterns in the appearance of clouds.
3. Construct an explanation for the behavior of the system that results in the appearance of patterns in clouds.
4. Develop evidence to supports an explanation for the causes of cloud patterns.

Individual Performance

5. Write in your journal (I-pad or on a sheet of paper) an explanation for the causes of the patterns. Cite evidence to support your explanation.

Group Discussion

Science Reflection - Consider the sources of evidence used to support your explanation.

Teacher Reflection – Reflect on the role of Crosscutting Concepts for posing questions and students making sense of phenomenon.

	K-2	3-5	6-8	9-12
PS1.A Structure of matter	Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.	Matter exists as particles that are too small to see. Matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.	The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.	The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions and nuclear processes.
ESS2.C The roles of water in Earth's surface processes	Water is found in many types of places and in different forms on Earth.	Most of Earth's water is in the ocean and much of the Earth's fresh water is in glaciers or underground.	Water cycles among land, ocean, and atmosphere, and is propelled by sunlight and gravity. Density variations of seawater drive interconnected ocean currents. Water movement causes weathering and erosion, changing landscape features. Complex interactions determine local weather patterns and influence climate, including the role of the ocean.	The planet's dynamics are greatly influenced by water's unique chemical and physical properties.
ESS2.D Weather and climate	Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region and time. People record weather patterns over time.	Climate describes patterns of typical weather conditions over different scales and variations. Historical weather patterns can be analyzed.		The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system. Global climate models are used to predict future changes, including changes influenced by human behavior and natural

Core Ideas	K-2	3-5	6-8	9-12
PS4.A Wave properties	Sound can make matter vibrate, and vibrating matter can make sound.	Waves are regular patterns of motion, which can be made in water by disturbing the surface. Waves of the same type can differ in amplitude and wavelength. Waves can make objects move.	A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model can explain many phenomena including sound and light. Waves can transmit energy.	The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy.
PS2.A Forces and motion PS2.B Types of interactions	Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it.	The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force. Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object.	Forces at a distance are explained by fields that can transfer energy and can be described in terms of the arrangement and properties of the interacting objects and the distance between them. These forces can be used to describe the relationship between electrical and magnetic fields. Newton's 2^{nd} law (F=ma) and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.

Crosscutting Concepts

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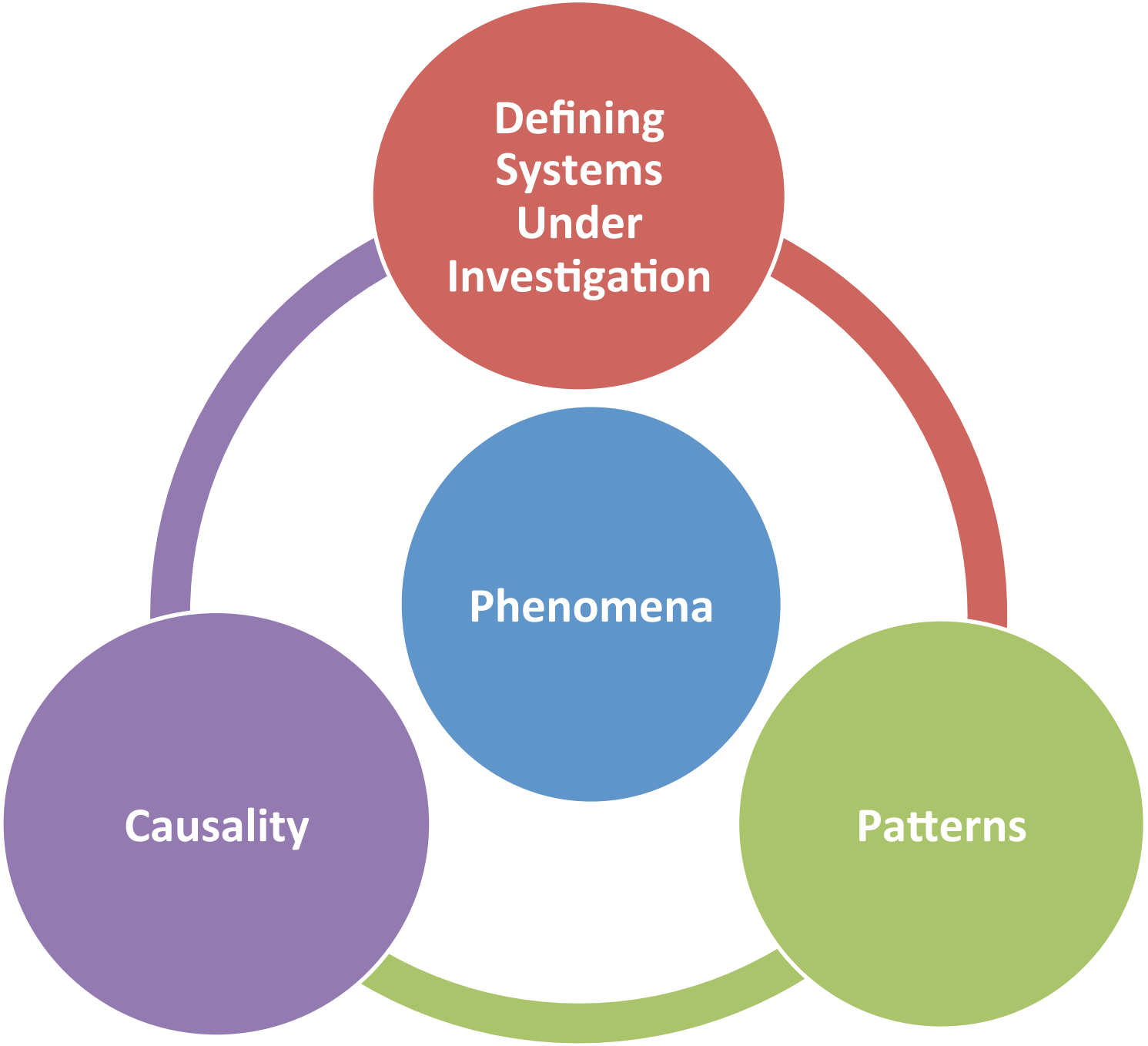
Scale, Proportion and Quantity

- In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.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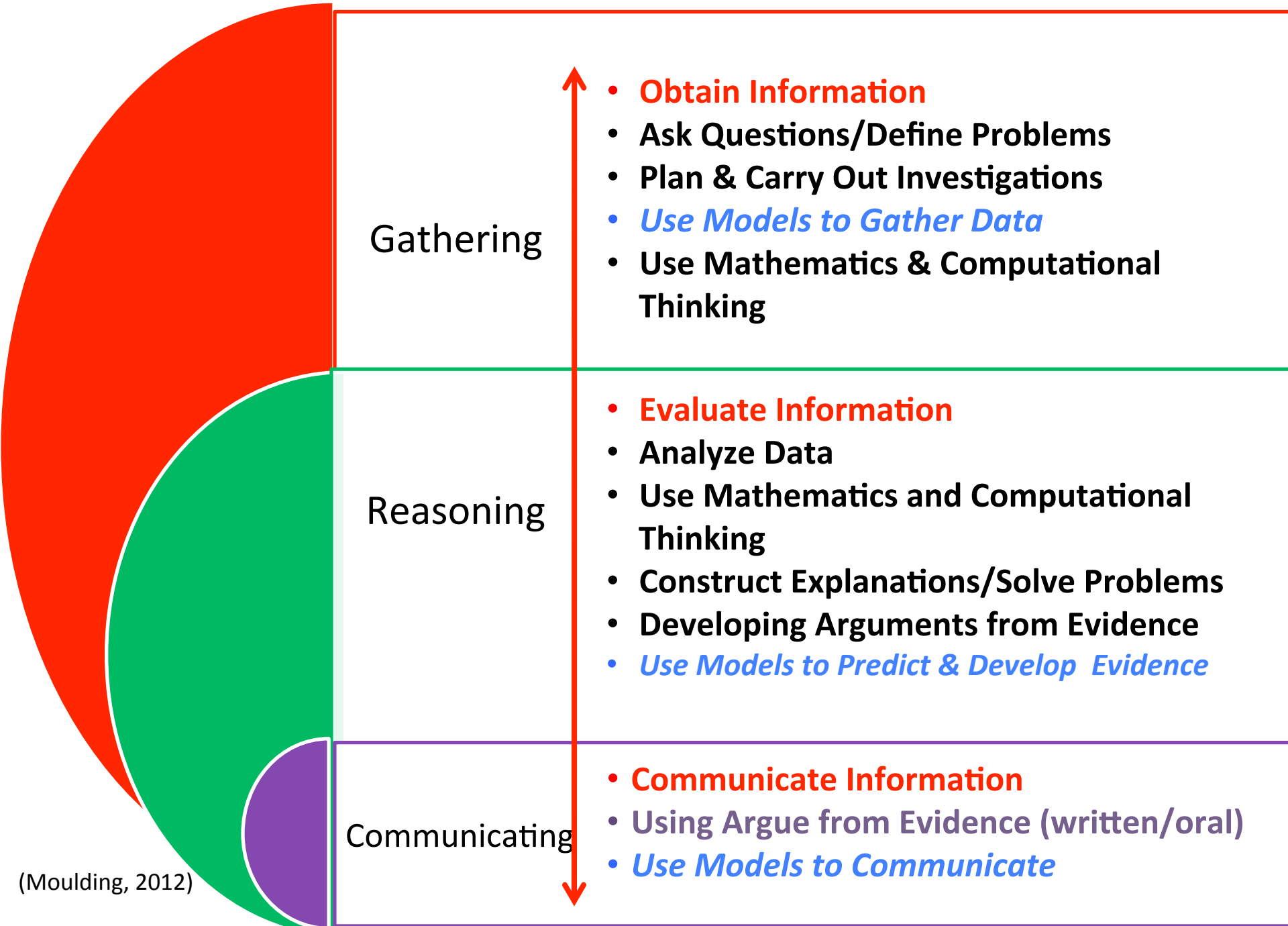

(Moulding, 2012)

Crosscutting Concepts Across Gathering, Reasoning, and Communicating Examples of Typical Performances

Gathering	Determining the **scale** of the **system** Determine the **proportion of the components in the system** Identifying the **changes** in the **system**
Reasoning	Determining the **cause and effect** relationships for phenomenon Analyze **patterns** in the phenomenon Analyze **changes** in the system Relate **structure and function** relationships to **causality** Evaluate the **cycling of matter** into, out of, and within the system Evaluate the **flow of energy** into, out of, and within the system
Communicating	Write, use models, and/or tell the **causes** of the phenomena in **systems** using **patterns** and core ideas as evidence to support explanations.

Crosscutting Concepts Across Gathering, Reasoning, and Communicating Examples of Typical Performances

Gathering	
Reasoning	
Communicating	

Discussion and Questions

Thank you,

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