ASET Crosscutting Concepts (CCC) Grade Band Descriptors

CCC 1	**Patterns:** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.		
K-2	**3-5**	**6-8**	**9-12**
Grade-band *descriptors:*			
a. Patterns in the natural and human designed world can be observed. b. Patterns can be used to describe phenomena and used as evidence.	a. Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products. b. Patterns of change can be used to make predictions. c. Patterns can be used as evidence to support an explanation.	a. Macroscopic patterns are related to the nature of microscopic and atomic-level structure. b. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. c. Patterns can be used to identify cause and effect relationships. d. Graphs, charts, and images can be used to identify patterns in data.	a. 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. b. 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. c. Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. d. Mathematical representations are needed to identify some patterns. e. Empirical evidence is needed to identify patterns.

Critical questions for patterns (A'Hearn, 2013)**:**

- Is there a pattern?
- What is the evidence for this pattern?
- Do similarities and differences reveal a pattern?
- Is this pattern real or imagined? (People sometimes see patterns where there isn't one)
- What predictions can I make based on this pattern? Can I test them?
- Is there a cause for this pattern?
- Engineering- How widely can this pattern be applied? What are its limits? Can I use this pattern to design a solution?
- What other crosscutting concepts can be applied to this pattern?
- How does this pattern compare to other patterns I have learned about?
- Based on what I've learned, what other symbol could be used to represent patterns?

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CCC 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	**3-5**	**6-8**	**9-12**
Grade-band *descriptors:*			
a. Events have causes that generate observable patterns. b. Simple tests can be designed to gather evidence to support or refute student ideas about causes.	a. Cause and effect relationships are routinely identified, tested, and used to explain change. b. Events that occur together with regularity might or might not be a cause and effect relationship.	a. Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. b. Cause and effect relationships may be used to predict phenomena in natural or designed systems. c. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	a. Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. b. 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. c. Systems can be designed to cause a desired effect. d. Changes in systems may have various causes that may not have equal effects.

Critical questions for Cause and Effect (A'Hearn, 2013)**:**

- What evidence is there for a cause and effect relationship?
- How can this cause and effect relationship be tested?
- What are other possible causes? Are there many causes?
- Is the cause and effect relationship real or imagined?
- How is this cause and effect relationship similar to and different than others I have learned about?
- Engineering- How can I use this cause and effect relationship?
- What other crosscutting concepts apply to this cause and effect relationship?
- Based on what I've learned, what other symbol could be used to represent Cause and Effect?

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CCC 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	**3-5**	**6-8**	**9-12**
Grade-band *descriptors:*			
a. Relative scales allow objects and events to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). b. Standard units are used to measure length.	a. Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods. b. Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.	a. Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. b. The observed function of natural and designed systems may change with scale. c. 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. d. Scientific relationships can be represented through the use of algebraic expressions and equations. e. Phenomena that can be observed at one scale may not be observable at another scale.	a. The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. b. Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. c. Patterns observable at one scale may not be observable or exist at other scales. d. Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. e. 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).

Critical questions for Scale, Proportion, and Quantity (A'Hearn, 2013)**:**

- How would the phenomenon we are studying look at the micro or nano scale?
- How does this interaction affect the global scale?
- How does this system look at smaller and larger scales? What is new and what is the same?
- Engineering- Can we make this bigger or smaller? How will it change if we do?
- Engineering- What is involved in making this process take place at an industrial scale?
- How does this scale relate to you? How much bigger or smaller is it than what you are used to experiencing?
- How can we study nature at this scale?
- How can we accurately measure this at this scale?
- How are the other crosscutting concepts affected at this scale? How are they affected if we change scale?
- Based on what I've learned, what other symbol could be used to represent Scale, Proportion, and Quantity?

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CCC 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. As science instruction progresses, so too should students' ability to analyze and model more complex systems and to use a broader variety of representations to explicate what they model. Their thinking about systems in terms of component parts and their interactions, as well as in terms of inputs, outputs, and processes, gives students a way to organize their knowledge of a system, to generate questions that can lead to enhanced understanding, to test aspects of their model of the system, and, eventually, to refine their model.		
K-2	**3-5**	**6-8**	**9-12**
Grade-band *descriptors:*			
a. Objects and organisms can be described in terms of their parts. b. Systems in the natural and designed world have parts that work together.	a. A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. b. A system can be described in terms of its components and their interactions.	a. Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. b. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. c. Models are limited in that they only represent certain aspects of the system under study.	a. Systems can be designed to do specific tasks. b. 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. c. 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. d. 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.

Critical questions for Systems and System Models (A'Hearn, 2013)**:**

- What are the limits of this system?
- What other systems affect this system? How?
- What parts and sub-systems make up this system? How do they work together?
- What are the inputs and outputs of this system?
- What interactions and processes involve this system?
- What are the advantages to thinking about this as a system?
- In what ways is this system like others I have learned about? How is it different?
- Engineering- How can we improve the function of the system?
- What is accurate and inaccurate about our model of this system?
- How can our systems model be made more accurate?
- What other crosscutting concepts apply to this system?
- Based on what I've learned, what other symbol could be used to represent Systems and Systems Models?

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CCC 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	**3-5**	**6-8**	**9-12**
Grade-band *descriptors:*			
a. Objects may break into smaller pieces, be put together into larger pieces, or change shapes.	a. Matter is made of particles. b. 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. c. Energy can be transferred in various ways and between objects.	a. Matter is conserved because atoms are conserved in physical and chemical processes. b. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. c. Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). d. The transfer of energy can be tracked as energy flows through a designed or natural system.	a. The total amount of energy and matter in closed systems is conserved. b. 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. c. Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. d. Energy drives the cycling of matter within and between systems. e. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Critical questions for Energy and Matter (A'Hearn, 2013)**:**

- How are energy and matter related in this system?
- Where does the energy for this system come from? Where does it go?
- What does energy do in the system? How is it changed?
- What is the role of matter in this system? How does it change? How does it enter and exit the system?
- Is the role of energy and matter in this system similar to other systems I have learned about? How is it different?
- Engineering (energy)- How can we improve the energy efficiency of this system?
- Engineering (matter)- If we change the materials, does that improve the system?
- How do the energy and matter in this system relate to other crosscutting concepts?
- Based on what I've learned, what other symbol could be used to represent Energy and Matter?

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CCC 6	**Structure and Function:** The way an object is shaped or structured determines many of its properties and functions.		
K-2	**3-5**	**6-8**	**9-12**
Grade-band *descriptors:*			
a. The shape and stability of structures of natural and designed objects are related to their function(s).	a. Different materials have different substructures, which can sometimes be observed. b. Substructures have shapes and parts that serve functions	a. 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. b. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.	a. 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. b. 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

Critical questions for Structure and Function (A'Hearn, 2013)**:**

- How does the function depend on the structure?
- How does the structure support the function?
- Are there other structures that can serve the same function?
- How does this relationship between structure and function compare to others that I have learned about?
- Engineering- How can the structure be improved?
- How does the structure limit the function?
- How do other crosscutting concepts relate to this structure?
- Based on what I've learned, what other symbol could be used to represent Structure and Function?

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CCC 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	**3-5**	**6-8**	**9-12**
Grade-band *descriptors:*			
a. Some things stay the same while other things change. b. Things may change slowly or rapidly.	a. Change is measured in terms of differences over time and may occur at different rates. b. Some systems appear stable, but over long periods of time will eventually change.	a. 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. b. Small changes in one part of a system might cause large changes in another part. c. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. d. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms.	a. Much of science deals with constructing explanations of how things change and how they remain stable. b. Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. c. Feedback (negative or positive) can stabilize or destabilize a system. d. Systems can be designed for greater or lesser stability.

Critical questions for Stability and Change (A'Hearn, 2013):

- What causes change in this system?
- What causes stability in this system?
- Are there feedbacks that make this system more or less stable?
- Engineering- How can we make the system more stable? How can we make it change?
- What is the time scale for this system to remain stable or change?
- If the system is stable, what would cause it to change?
- If the system is changing, what would make it become stable?
- Is the stability static or dynamic?
- How does stability and change in this system compare with other systems I have learned about?
- What other crosscutting concepts relate to stability and change in this system?
- Based on what I've learned, what other symbol could be used to represent Stability and Change?

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