K – 12 Crosscutting Concepts

The crosscutting concepts bridge disciplinary boundaries, having explanatory value throughout much of science and engineering. These 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. 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. These 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.

The seven crosscutting concepts include:

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change

K – 2	3 – 5	6 – 8	9 – 12
Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.			
Students recognize that patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	Students identify similarities and differences in order to sort and classify natural objects and designed products.	Students recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure.	Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena.
	Students identify patterns related to time, including simple rates of	Students identify patterns in rates of change and other numerical relationships that provide	Students recognize classifications or explanations used at one scale may not be useful or need revision using a

	change and cycles, and to use these patterns to make predictions.	information about natural and human designed systems.	different scale; thus requiring improved investigations and experiments.
		Students use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data.	Students use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.
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.			
Students learn that events have causes that generate observable patterns.	Students routinely identify and test causal relationships and use these relationships to explain change.	Students classify relationships as causal or correlational and recognize that correlation does not necessarily imply causation.	Students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects.
Students design simple tests to gather evidence to support or refute their own ideas about causes.	Students understand events that occur together with regularity might or might not signify a cause and effect relationship.	Students use cause and effect relationships to predict phenomena in natural or designed systems.	Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems.
		Students understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	Students propose causal relationships by examining what is known about smaller scale mechanisms within the system.
			Students recognize changes in systems may have various causes that may not have equal effects.

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.			
Students use relative scales (e.g., bigger and smaller; hotter and colder; faster and slower) to describe objects.	Students recognize natural objects and observable phenomena exist from the very small to the immensely large.	Students observe time, space, and energy phenomena at various scales using models to study systems that are too large or too small.	Students understand the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
Students use standard units to measure length.	Students use standard units to measure and describe physical quantities such as weight, time, temperature, and volume.	Students understand phenomena observed at one scale may not be observable at another scale, and the function of natural and designed systems may change with scale.	Students recognize patterns observable at one scale may not be observable or exist at other scales, and some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
		Students use proportional relationships (e.g., speed as the ratio of distance traveled to time taken) to gather information about the magnitude of properties and processes.	Students use orders of magnitude to understand how a model at one scale relates to a model at another scale.
		Students represent scientific relationships through the use of algebraic expressions and equations.	Students use algebraic thinking to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).
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.			
Students understand objects and organisms can be described in terms of their parts; and systems in the natural and designed world have parts that work together.	Students understand 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 understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.	Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs.

	Students can describe a system in terms of its components and their interactions.	Students can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.	Students can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales.
		Students can learn that models are limited in that they only represent certain aspects of the system under study.	Students can use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models.
			Students can design systems to do specific tasks.
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.			
Students observe the shape and stability of structures of natural and designed objects are related to their function(s).	Students learn matter is made of particles and energy can be transferred in various ways and between objects.	Students learn matter is conserved because atoms are conserved in physical and chemical processes.	Students learn that the total amount of energy and matter in closed systems is conserved
	Students observe the conservation of matter by tracking matter flows and cycles before and after processes and recognizing the total weight of substances does not change.	Students learn within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.	Students can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system.
		Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).	Students learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems.

		The transfer of energy can be tracked as energy flows through a designed or natural system.	Students understand energy drives the cycling of matter within and between systems.
			Students understand in nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.
Structure and function. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.			
Students observe the shape and stability of structures of natural and designed objects are related to their function(s).	Students learn different materials have different substructures, which can sometimes be observed; and substructures have shapes and parts that serve functions.	Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts.	Students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem.
		Students analyze many complex natural and designed structures and systems to determine how they function.	Students infer the functions and properties of natural and designed objects and systems from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials.
		Students design structures to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.	
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.			
Students observe some things stay the same while other things change,	Students measure change in terms of differences over time, and	Students explain stability and change in natural or designed systems by examining changes over time, and	Students understand much of science deals with constructing explanations

and things may change slowly or rapidly.	observe that change may occur at different rates.	considering forces at different scales, including the atomic scale.	of how things change and how they remain stable.
	Students learn some systems appear stable, but over long periods of time they will eventually change.	Students learn 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	Students quantify and model changes in systems over very short or very long periods of time.
			Students see some changes are irreversible, and negative feedback can stabilize a system, while positive feedback can destabilize it.
			Students recognize systems can be designed for greater or lesser stability.