Crosscutting Concepts

Patterns: Looking for patterns in nature can help scientists understand relationships, prompt questions about what causes things to work, and organize/group important things into categories

- Large patterns in nature are often caused by very small structures such as the atoms and molecules involved
- Patterns in the rates of change can provide information about natural and human designed systems.
- Patterns can be used to identify cause and effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Cause and Effect: *Events have causes, sometimes there is one cause while other times there many causes. Determining the causes of relationships and what factors influence them is a major activity of science and engineering.*

- Relationships should be classified as either related by causation or correlation. Sometimes variables are related to each other (correlated), but that does not mean that one variable is always the cause of the change in the other variable.
- Cause and effect relationships can help predict phenomena in natural or designed systems.
- Phenomena may have more than one cause.
- Some cause and effect relationships in systems can only be described using probability.

Scale, Proportion, and Quantity: *In considering phenomena, it is critical to recognize the changes that occur with different sizes, lengths of time, and amounts of energy. When different quantities or scales change, the proportional relationships between variables can change as well*

- Scientists use models to study systems that are too large or too small.
- The way a natural and designed systems works may change with scale.
- Ratios can be used to understand the relationships between different variables.
- Proportional relationships can provide information about phenomena. By using proportions, scientists can learn about the properties of the materials involved and about the processes involved in the phenomena.
- Searching for proportional relationships in data can help determine if the variables have a linear or exponential relationship.
- Scientific relationships can be represented through the use of algebraic expressions and equations.
- Phenomena that can be observed at one scale may not be observable at another scale.

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.*

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
- Models are limited in that they only represent certain aspects of the system under study. It is important to note the limitations of models.

Energy and Matter: *Tracking energy and matter through systems helps scientists understand their system's behavior. When tracking energy and matter, it is important to recognize the that matter and energy is always conserved within the system.*

- Matter is conserved because atoms are conserved in physical and chemical reactions.
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. If matter is moving, energy transfer is causing it.
- Energy may take different forms (e.g. electromagnetic, thermal energy, energy of motion). Energy may change between these forms, but the amount of energy is always conserved.
- The transfer of energy can be tracked, or followed, as energy flows through a designed or natural system.

Structure and Function: *The way an object is shaped or structured helps it do its job*

- The functions of objects or systems depend on their shapes, what they are made out of (composition); therefore, by looking at the structures of objects and systems, scientists can figure out how they work.
- When scientists design things, they have to consider the properties of the materials they are using. They also have to consider how the materials will be shaped and how the shape connects to the function.

Stability and Change: *For both designed and natural systems, it is important to consider and understand the factors that will affect the stability of the system.*

- In nature, systems want to reach stability.
- It is important to look at changes over time.
- In order to determine the factors that affect stability, consider the forces that are influencing it at different scales.
- Small changes in one part of a system might cause large changes in another part.
- Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
- Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. Systems are trying to reach a balance; changing one variable can result in other variables changing to maintain this balance.
- Often systems reach equilibrium by moving from high to low concentrations or quantities.

*Adapted from the NSTA