Recurring Themes and Concepts

This resource addresses the recurring themes and concepts through the lenses of both scientists and engineers. Scientists seek to develop scientific explanations, and engineers seek to develop designed solutions. The recurring themes and concepts provide a connective structure that supports students' understanding of science and the application of science through engineering.

The K-8 recurring themes and concepts strand introduces and spirals the recurring themes throughout each grade level's Texas Essential Knowledge and Skills (TEKS). In high school, the recurring themes and concepts connections are addressed more broadly to include structure and function, systems, models, and patterns. The high school course introductions explain that all systems have basic properties that can be described in space, time, energy, and matter. Change and constancy occur in systems as patterns and can be observed, measured, and modeled. Models have limitations but provide a tool for understanding the ideas presented. Scientists and engineers analyze a system in terms of its components and how they relate to each other, the whole, and the external environment.

Patterns

Patterns are regular sequences that can be found throughout nature.

Scientists	**Engineers**
Scientists questions may be generated when scientists observe a pattern of events or when something does not match an established pattern. Scientists can use patterns to classify objects or phenomena, for example, day and night, moon phases, life cycles, or other repeating designs.	Engineering use scientific knowledge to develop or improve objects, systems, or processes. Engineers use patterns found in scientific data to make data-informed decisions during the engineering design process. Engineers may diagnose patterns of failure in a designed system and improve the design or analyze patterns such as daily and seasonal use of power to design a system that can meet fluctuating needs.

Cause and Effect Relationships

Cause and effect relationships are relationships between two or more variables or phenomena whereby one variable or event leads to a predictable response. Events have causes, sometimes simple, sometimes multifaceted.

Scientists	**Engineers**
Scientists attempt to uncover and understand cause-and-effect relationships through scientific investigations. Scientists analyze the causes of the patterns they observe, including how and why phenomena occur and if the occurrences of these patterns are conditional. For example, scientists investigate cause and effect mechanisms in the motion of a single object, specific chemical reactions, population changes in an ecosystem or a society, and the development of holes in the polar ozone layers.	In engineering, the goal is to design a system to cause the desired effect. Engineers must understand the underlying causal relationships to devise and explain a design that can achieve a specified objective. They seek answers to the questions that explain system relationships. Engineers analyze how particular elements affect the functionality and cost of a design. The application's quality or solution can often be improved as knowledge of the relevant relationship is improved.

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Scale, Proportions, and Quantity

Scale is a ratio between two sets of measurements. **Proportion** is an equation showing two equivalent ratios. **Quantity** is a count of a set of objects or a measurement of a substance.

Scientists	Engineers
In thinking scientifically about systems and processes, it is essential to recognize that they vary in size. Scientists study natural phenomena that span full scales of size, time, and energy, from very small to very large. Scientists can make macroscopic observations through direct observation with the naked eye. They use experimental techniques and tools to observe other scales that may be too small or large or too slow or fast to observe directly.	A proper understanding of scale relationships is critical to engineering. Structures cannot be conceived or constructed without an engineer's precise sense of scale.

Overview

Both scientists and engineers use proportionality and ratios to understand quantity and scale and the relationship between physical characteristics. To appreciate the relative magnitude of some properties or processes, it may be necessary to grasp the relationships among different types of quantities. For example, speed is the ratio of distance traveled to time taken, and density is the ratio of mass to volume.

Systems

Systems are regularly interacting or interdependent groups of items forming a unified whole. Systems are made up of components and have defined boundaries. Systems can interact with other systems or be components of larger systems

Scientists	Engineers
For investigation purposes, scientists often study smaller units of investigations, or "systems." Systems can consist, for example, of organisms, machines, fundamental particles, galaxies, ideas, and numbers. Systems have boundaries, components, resources, flow, and feedback. In laboratory or field research, an essential element affecting the design of an investigation and the interpretation of results is the extent to which the system can be physically isolated or the external conditions controlled.	Engineers predict a system's behaviors and diagnose problems or failures in system functioning. For example, in a simple mechanical system, interactions among the parts are describable in terms of forces among them that cause changes in motion or physical stresses. Consideration of flows into and out of the system is a crucial element of system design. Systems thinking and system models support critical steps in developing, sharing, testing, and refining design ideas.

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Matter & Energy

Matter is a material substance that occupies space, has mass, and is composed predominantly of microscopic particles. **Matter** can be understood in terms of the types of particles present and their interactions. **Energy** is a measurable quantity that describes how much change can occur within a system.

Scientists	Engineers
Scientists investigate the flow and interactions of matter and energy. The states, properties, and reactions of matter can be described and predicted based on the types, interactions, and motions of atoms. Energy manifests in multiple phenomena, such as motion, light, sound, electrical and magnetic fields, and thermal energy. Energy can be modeled as either motion of particles or as stored in force fields (electric, magnetic, gravitational) that mediate interactions between particles. The total energy in a system does not change but can be transferred between objects within the system.	Considering energy and matter inputs, outputs, and flows or transfers within a system or process is equally important for engineering. A goal in engineering design is to maximize certain types of energy output while minimizing others and optimizing energy inputs needed to achieve the desired task. For example, engineers might develop ways to transform wind and wave energy at sea into usable electricity for people in coastal regions and beyond.

Structure and Function

A **structure** is something arranged in a definite pattern of organization; the arrangement of particles or parts in a substance or body; the aggregate of elements of an entity in their relationships to each other. A **function** is the purpose or reason an object exists in a system. How a structure functions, whether natural or designed by humans, depends on how essential parts are shaped and the relationships between those parts

Scientists	Engineers
Scientists seek to understand how the structure of an organism or type of matter is related to how it behaves or what it does. The functioning of natural systems depends on the relationships of certain essential parts and the properties of the materials from which they are composed. A sense of scale is necessary to know what properties and aspects of shape or material are relevant at a particular magnitude or when investigating specific phenomena.	Engineers consider the intended function of a design when developing its structure and determining its design features. Form is dependent on function. For example, a vehicle that a person will navigate would be designed differently than one that will be operated remotely.

Stability

Stability denotes a condition in which some aspects of a system are unchanging, the scale at which it is observed. Stability means that a small disturbance will fade away—that is, the system will stay in, or return to, a stable condition.

Scientists	Engineers
Scientists investigate what range of conditions can lead to a system's stable operation and what changes would destabilize it (and in what ways). Any system has a range of conditions under which it can operate in a stable fashion and conditions under which it cannot function. For example, a particular living organism can survive only within a specific range of temperatures; outside that span, it will die.	In designing systems for stable operation, the mechanisms of external controls and internal feedback loops are essential to design elements. Understanding the feedback mechanisms that regulate the system's stability or that drive its instability provides insight into how the system may operate under various conditions. Evaluating these mechanisms is essential when comparing different design options that address a particular problem.

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