Crosscutting Concepts Matrix for PESTL – Secondary

1. ***Patterns, Similarity, and Diversity*** – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying the patterns.

Identify and Describe	*Model and Predict*	*Explanations and Solutions*	*Compare, Analyze, and Apply*
▪ Identify and describe patterns in the natural world. ▪ Identify and describe patterns of symmetry in nature. ▪ Identify and describe the purpose for patterns in engineered objects.	▪ Use models to investigate patterns in phenomena. ▪ Use patterns to make predictions. ▪ Use patterns to identify and classify objects, mechanism, and organism. ▪ Develop warranted inferences from patterns observed in data. ▪ Use patterns in rates of change and mathematical relationships to develop information about how natural and human designed systems operate.	▪ Use patterns as evidence to support science explanations. ▪ Use patterns as evidence to support arguments. ▪ Use patterns of performance to analyze design solutions. ▪ Use patterns to explain cause and effect relationships.	▪ Analyze phenomena for evidence of patterns. ▪ Analyze data to determine patterns. ▪ Analyze patterns that are related to time. ▪ Use graphs and charts to investigate and analyze patterns in data. ▪ Relate macroscopic patterns to the nature of microscopic and atomic-level structure. ▪ Use mathematical representations to analyze patterns.

2. ***Cause and Effect: Mechanism and Prediction*** – Events have causes, sometimes simple, sometime multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science.

Identify and Describe	*Model and Predict*	*Explanations and Solutions*	*Compare, Analyze, and Apply*
▪ Identify and describe the causes of phenomena. ▪ Describe the conditions necessary for phenomena to occur (e.g., temperature necessary for seeds to germinate, temperature for a chemical reaction to occur). ▪ Identify the causes of observed patterns in natural systems. ▪ Describe the likelihood of a cause and effect relationship occurring in terms of probability.	▪ Use patterns to determine the causes of observed phenomena. ▪ Examine small-scale systems to predict cause and effect relationships of larger scale phenomena. ▪ Use cause and effect relationships to predict the frequency of phenomena. ▪ Justify predictions using cause and effect relationships.	▪ Use evidence to support explanations for the causes of phenomena. ▪ Explain order of events necessary to cause a phenomenon to occur. ▪ Design and build machines capable of performing specified tasks. ▪ Design and/or analyze systems that cause a desired effect.	▪ Compare multiple causes contributing to one phenomenon. ▪ Analyze the relative impacts of various causes contributing to a change. ▪ Analyze the scale of the effect of changes in systems. ▪ Use empirical evidence to distinguish between causal and correlational relationships. ▪ Analyze data to determine if relationships are causal or correlational.

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.

Identify and Describe	*Model and Predict*	*Explanations and Solutions*	*Compare, Analyze, and Apply*
▪ Describe phenomena that can be observed at one scale; but may not be observable at another scale. ▪ Use measurement to compare objects. ▪ Use mathematical relationships to describe objects. ▪ Describe the movement of objects specific to time scales (e.g., orbit of planets, movement of tectonic plates). ▪ Use algebraic thinking to examine data and predict the effect of one variable on another (e.g., linear growth, exponential growth).	▪ Use scale, proportion, and quantity to model systems. ▪ Predict changes over time. ▪ Use measurement to compare phenomena represented by models. ▪ Develop models of events using accurate time scales. ▪ Use mathematical algebraic expressions and equations to explain scientific relationships. ▪ Use models to examine systems that are too small, too large, too fast, or too slow to observe directly. ▪ Use models at one scale to understand phenomena at a different order of magnitude.	▪ Use patterns that can be observed at one scale to explain phenomena at another scale. ▪ Use ratio to support explanations (e.g., more dense objects sink, force of a moving object increases as speed and mass increases). ▪ Use proportion and quantity to support explanations. ▪ Use quantitative reasoning to compare solutions to problems.	▪ Use proportional relationships (e.g., density, speed, concentration) to analyze the components of a system. ▪ Compare objects and systems that are at the same scale. ▪ Compare microscopic organisms to macroscopic scales. ▪ Compare distances at various scales. ▪ Compare the motion of objects across various distances. ▪ Use geologic time lines and scales to compare events in the past.

4. ***Systems and System Models –*** Delimiting and defining the system under study and making a model of it are tools used throughout science and engineering for developing understanding.

Identify and Describe	*Model and Predict*	*Explanations and Solutions*	*Compare, Analyze, and Apply*
▪ Describe the interactions of specific components of systems. ▪ Describe energy inputs to systems that cause changes. ▪ Describe systems in terms of interactions and components. ▪ Describe systems that interact with other systems and are part of larger, more complex systems. ▪ Describe the limitations of models in terms of precision and reliability for predictions.	▪ Use diagrams and representations to model systems. ▪ Use conceptual models to represent systems. ▪ Use models to represent the inputs, outputs, cycling, and flow of matter and energy in systems. ▪ Use models to predict the behavior of a system.	▪ Explain interactions across multiple systems. ▪ Explain the inputs and outputs of matter, energy, and forces in a system. ▪ Develop explanations for the role of various components of systems. ▪ Design systems to do specific tasks.	▪ Analyze interactions within a system and across multiple systems. ▪ Analyze the limitations of models that are used to represent specific aspects of systems. ▪ Evaluate limitations of an investigation of complex systems. ▪ Evaluate the degree to which an investigation defines the boundaries of a system.

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.

Identify and Describe	*Model and Predict*	*Explanations and Solutions*	*Compare, Analyze, and Apply*
▪ Distinguish between the common use of the word *energy* and the way science uses the word. ▪ Describe the transfer of energy. ▪ Describe the role of energy in causing changes (e.g., heat evaporates water, energy lifting an object). ▪ Account for the conservation of energy in a system. ▪ Account for the conservation of matter in a system.	▪ Use principles of conservation of matter and energy to predict changes in systems. ▪ Use models to describe the flow of energy. ▪ Use the particle model to describe matter cycling. ▪ Use models to trace the flow of energy in systems.	▪ Use energy flow to explain changes in systems. ▪ Use matter cycles to explain cycles in systems. ▪ Explain matter cycles in terms of the flow of energy in systems. ▪ Explain the relationship of energy to changes in matter. ▪ Explain how energy is involved when matter changes. ▪ Explain the transformation of energy in systems.	▪ Analyze the conservation of energy and matter in complex systems. ▪ Analyze the flow of energy and cycling of matter into, out of, and within a system. ▪ Analyze nuclear processes in terms of the conservation of the total number of protons and neutrons.

6. ***Structure and Function*** – The way an object is shaped or structured determines many of its properties and functions.

Identify and Describe	*Model and Predict*	*Explanations and Solutions*	*Compare, Analyze, and Apply*
▪ Identify the attributes of a structure that contribute to stability (e.g., diagonal bracing, spherical share). ▪ Relate the structure to the mechanical functioning of a machine or organism. ▪ Investigate phenomena and describe the structure/function relationships.	▪ Describe how the materials that objects are constructed from affect the function of the object. ▪ Investigate or design new systems or structures for the properties of material and the structure of different components to revel function. ▪ Use models to visualize and describe how a system's function depends on the shapes, composition, and relationships among parts.	▪ Explain the function of microscopic structures on organisms. ▪ Develop explanations for phenomena based on structure and function relationships. ▪ Design structures that utilize specific properties of materials to best serve a specific function.	▪ Analyze the design of mechanical systems in terms of structure and function. ▪ Infer the properties and function of a natural or designed system based on overall structure, components, and molecular properties. ▪ Compare the structure of substances in various phases to the way they function. ▪ Analyze complex and microscopic structures and systems by using models to determine how they operate.

7. ***Stability and Change*** – For both designed and natural systems, conditions of stability, and factors that control rates of change are critical elements to consider and understand.

Identify and Describe	*Model and Predict*	*Explanations and Solutions*	*Compare, Analyze, and Apply*
▪ Distinguish between events that are changing and ones that are stable. ▪ Describe stability and change in terms of time scales. ▪ Describe systems in terms of stability and change. ▪ Identify things that trigger changes to a system that was previously stable. ▪ Describe changes to stability in terms of sudden events or gradual changes over time. ▪ Describe systems that are stable over very long periods of time.	▪ Use models to predict changes in stable systems to changes in unstable systems. ▪ Use models to describe opposing forces that result in stability. ▪ Model systems in dynamic equilibrium. ▪ Use mathematical relationships to model change and rates of change over short and very long periods.	▪ Explain changes in a system in terms of inputs and outputs. ▪ Explain the necessary attributes of stable systems. ▪ Explain patterns of change overtime. ▪ Explain phenomena in terms of equilibrium. ▪ Explain the stability and change in natural systems over time and at multiple scales. ▪ Explain how feedback mechanisms keep systems in equilibrium. ▪ Design systems for greater or lesser stability.	▪ Compare systems that are stable at one scale and not stable on another scale. ▪ Analyze patterns of change and stability. ▪ Analyze the attributes of systems engineered for stability or controlled change. ▪ Analyze how small changes in a system may lead to large changes parts of the system. ▪ Evaluate systems in terms of how specific components of the system change and/or remain stable.