MESA PUBLIC SCHOOLS
MESA, ARIZONA

Science

High School Curriculum Guides

including

Standards, Three Dimensional Foundations, and Evidence of Learning Specifications

Board Approval February 2020

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Introduction

Scientific thinking enables Arizona students to strengthen skills that people use every day: solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing lifelong learning. A fundamental goal of science education is to help students determine how the world works and make sense of phenomena in the natural world. Phenomena are events or situations that are observed to exist or happen, especially phenomena whose causes or explanations are in question. Science sense-making is a conceptual process in which a learner actively engages with phenomena in the natural world to construct logical and coherent explanations that incorporate their current understanding of science or a model that represents it and are consistent with the available evidence. To develop a scientific understanding of the natural world, students must be able to ask questions, gather information, reason about that information and connect it to scientific principles, theories, or models, and then effectively communicate their understanding and reasoning.

These standards outline what all students need to know, understand, and be able to do by the end of high school and reflect the following shifts for science education:

- Organize standards around thirteen core ideas and develop learning progressions to coherently and logically build scientific literacy from kindergarten through high school.
- Connect **core ideas**, **crosscutting concepts**, and **science and engineering practices**, to make sense of the natural world and understand how science and engineering are practiced and experienced.
- Focus on fewer, broader standards that allow for greater depth, more connections, deeper understanding, and more applications of content.

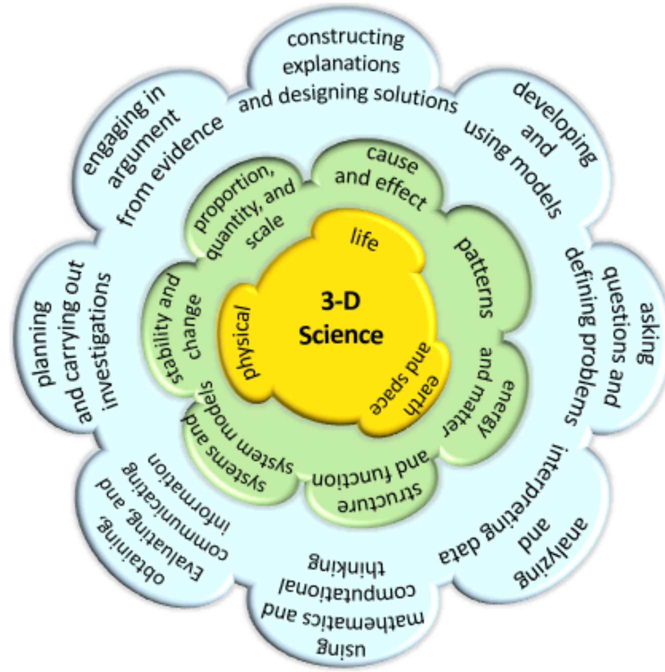

Figure 1: Three Dimensions of Science Instruction

Three Dimensions of Science

Sense-making in science occurs with the integration of three essential dimensions:

- **science and engineering practices** (shown as the outer ring in Figure 1)
- **crosscutting concepts** (shown as the middle section of Figure 1)
- **core ideas** (shown as the center circle in Figure 1)

Science and Engineering Practices

For decades teachers have utilized the scientific method as a methodology to engage in scientific inquiry. How it has been implemented in classrooms describes a set of prescribed steps used to engage in science teaching and to learn in a rather linear process. The new vision calls for students to engage in multifaceted science and engineering practices in more complex, relevant, and authentic ways. The science and engineering practices describe a robust process for how scientists investigate and build models and theories of the natural world or how engineers design and build systems. Rather than a linear process from hypothesis to conclusion, these practices reflect science and engineering as they are practiced and experienced. As students conduct investigations, they engage in multiple practices as they gather information to solve problems, answer their questions, reason about how the data provide evidence to support their understanding, and then communicate their understanding of phenomena. Student investigations may be observational, experimental, use models or simulations, or use data from other sources. These eight practices identified in *A Framework for K-12 Science Education* are critical components of scientific literacy, not instructional strategies:

- ask questions and define problems
- develop and use models
- plan and carry out investigations
- analyze and interpret data
- use mathematics and computational thinking
- construct explanations and design solutions
- engage in argument from evidence
- obtain, evaluate, and communicate information

While the scientific method is still being widely used, and a part of academics, the science and engineering practices are expected to be integrated with the core ideas and crosscutting concepts across all grade levels and disciplines.

Crosscutting Concepts

Crosscutting concepts cross boundaries between science disciplines and provide an organizational framework to connect knowledge from various disciplines into a coherent and scientifically based view of the world. They bridge boundaries between science and other disciplines and connect core ideas and practices throughout the fields of science and engineering. Their purpose is to provide a lens to help students deepen their understanding of the core ideas as they make sense of phenomena in the natural and designed worlds. The crosscutting concepts identified in *A Framework for K-12 Science Education* are:

- patterns
- cause and effect
- structure and function
- systems and system models
- stability and change
- scale, proportion, and quantity
- energy and matter

The Arizona Science Standards are designed for students to develop their understanding of core ideas through the lens of one or multiple crosscutting concepts. Crosscutting concepts can be combined as students find and use patterns as evidence, determine cause and effect relationships, or define systems to investigate. Students must be provided with structures and opportunities to make explicit connections between their learning and the crosscutting concepts.

The use of crosscutting concepts can be demonstrated within cause and effect relationships. For example, researchers investigate cause and effect mechanisms in the motion of a single object, specific chemical reactions, population changes in an ecosystem, and the development of holes in the polar ozone layers. Patterns are present in all science disciplines, and much of science is about explaining observed patterns. Using data, graphs, charts, maps, and statistics in combination with the science and engineering practices, students can use their knowledge of cause and effect relationships to formulate investigations, answer questions, and make informed predictions about observed phenomena.

Core Ideas

The Arizona Science Standards focus on thirteen core ideas in science and engineering, adapted from *Working with Big Ideas of Science Education*. The ten core ideas for **Knowing Science** center on understanding the causes of phenomena in physical, Earth and space, and life science. The three core ideas for **Using Science** connect scientific principles, theories, and models; engineering and technological applications; and societal implications to the content knowledge to support that understanding. The complexity of each core idea develops as students' progress through each grade band. Each standard is written at the intersection of two core ideas to help students understand both the process of knowing science and using science. These core ideas occur across grade levels and provide the background knowledge for students to develop sense-making around phenomena in the natural world.

Core Ideas for Knowing Science	Core Ideas for Using Science
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution. ***Adapted from *Working with Big Ideas in Science Education*[2]**	**U1:** Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. **U2:** The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. **U3:** Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

Coding of the High School Science Standards

In Arizona, students are required to take three credits of high school science aligned to standards in physical, earth and space, and life sciences to meet graduation requirements, but there is no mandatory course sequence across the state. Because of this, the high school standards are written at two levels: essential and plus. The term "plus" does not mean that the Plus Standards are optional or only for higher level courses.

Essential Standards:

- Intended for all students to have learned by the end of three credits of high school science courses
- May be assessed on the state science assessment
- Goal to prepare students for adult science literacy

Plus Standards:

- Supporting standards designed to be used with the essential standards
- For students taking a specific course in physics, chemistry, earth and space, and/or biology to prepare students for college-level courses
- Will be assessed by District

Like K-8, each high school standard represents the intersection of core ideas for knowing science and using science. This intersection stresses that content in physical science, earth and space science, and life science is not learned independently from ideas about the nature of science, applications of science, or the social implications of using science. The coding of the standard captures this intersection.

Standards v. Curriculum v. Instruction

Standards:

Standards are what a student needs to know, understand, and be able to do by the end of each grade. They build across grade levels in a progression of increasing understanding and through a range of cognitive demand levels. Standards are adopted at the state level by the Arizona State Board of Education.

Curriculum:

Curriculum refers to resources used for teaching and learning the standards. Curricula are adopted at the local level.

Instruction:

Instruction refers to the methods, or methodologies, used by teachers to teach their students. Instructional techniques are employed by individual teachers in response to the needs of the students in their classes to help them progress through the curriculum to master the standards. Decisions about instructional practice and techniques are made at a local level.

Time Allotment

The Arizona Science Standards suggest students have regular standards-based science instruction every year. The amount of time individual students need to learn these standards will vary. The chart below specifies the instructional time necessary for students to master these standards.

The Arizona Science Standards have been designed so that these time suggestions provide adequate time to actively engage in all 3 dimensions of science instruction to master the standards for each grade level. Depending on local factors, schools may allocate more or less time when determining curriculum programming within a specific context. Instruction on the Arizona Science Standards may be a dedicated time in the school schedule or may be integrated with the instruction of other subjects.

These time recommendations do not explicitly address the needs of students who are far below or far above the grade level. No set of grade-specific standards can fully reflect the variety of abilities, needs, learning rates, and achievement levels of students in any given classroom. The Arizona Science Standards do not define the intervention methods to support students who are far below or far above grade level or do not speak English as their first language.

Grade	K	1	2	3	4	5	6	7	8	HS
Suggested Minutes per Week	90	150	150	200	225	225	250	250	250	275
Suggested Average Minutes per Day	18	30	30	40	45	45	50	50	50	55

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A Look at the Arizona Science Standards for Mesa Public Schools

The 2018 Arizona Science Standards (AzSS) differ from prior science standards in that they integrate three dimensions (Core Ideas, Science and Engineering Practices, and Crosscutting Concepts) into a single standard document and have intentional connections between standards across all disciplines. The Mesa Public Schools Science Curriculum Guide highlights the Arizona Science Standard as well as each of the three integral dimensions and connections to other grade bands and subjects. This guide uses a table with three main sections.

What is Assessed (The Standard)

A standard describes what students should be able to do at the end of instruction and incorporates a Science and Engineering Practice and Core Idea. Standards are not instructional strategies or objectives for a lesson. Instead, they are intended to guide the development of assessments and are what a student needs to know, understand, and be able to do by the end of each grade. Standards build across grade levels in a progression of increasing understanding and through a range of cognitive demand levels.

3D Foundations Box

The three dimensions foundation box contains the learning goals that students should achieve. It is critical that science educators consider the foundations box an essential component when reading the AzSS and developing curricula. There are four main parts of the foundation box: Core Ideas, Science and Engineering Practices, Crosscutting Concepts, and Using Science, all of which are derived from *A Framework for Science Education* and *Working with Big Ideas of Science Education*. During instruction, teachers will need to have students use multiple practices to help students understand the Core Ideas. Most groupings of standards emphasize only a few practices or Crosscutting Concepts; however, all are emphasized within a grade band. The foundation box also contains Using Science (unique to AzSS) that connect scientific principles, theories, and models; engineering and technological applications; and societal implications to the content knowledge to support scientific understanding.

Evidence of Learning Specifications Box (EoLS)

The Evidence of Learning Specification box uses the standards and 3D foundations to develop EoLS, which describe what qualifies as evidence for students' proficiency. High quality assessment practices are critical to the success of the AzSS. The Evidence of Learning Specifications represent learning at the nexus of the 3-dimensions of the AzSS while engaged in AzSS phenomena.

Navigating the Science Curriculum Guide

Core Ideas for the Unit
Core Ideas as described below that will appear in the unit.

What is Assessed
A collection of one or more standards describing what students should be able to do at the end of instruction

Core Ideas
Concepts in science that that have broad importance within and across disciplines as well as relevance in people's lives

Science & Engineering Practices
Skills and knowledge that scientists and engineers engage in to either understand the world or solve a problem

Crosscutting Concepts
Ideas that are not specific to one discipline but cut across all disciplines

Using Science
Concepts that connect scientific principles, theories, and models; engineering and technological applications; and societal implications to the content knowledge to support scientific understanding.

Kindergarten Unit 2: Earth and Space Science

Kindergarten Unit 2

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Instructional Sequence 1

Az Science Standard K.E1U1.3

Observe, record, and ask questions about temperature, precipitation, and other weather data to identify patterns or changes in local weather.

CI E1 The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate

- Weather is determined by the conditions and movement of the air.
- The temperature, pressure, direction, speed of movement and the amount of water vapor in the air combine to create the weather.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions based on observations of the natural and/or designed world.

Mathematical and Computational Thinking:

- Use counting and numbers to identify and describe patterns in the natural and designed worlds.
- Describe, measure, and compare quantitative attributes of different objects and display the data using simple graphs.

Crosscutting Concepts

Patterns:

- Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

Cause and Effect:

- Events have causes that generate observable patterns.

Using Science – U1

- Science is about finding explanations for why things happen as they do or why they take a particular form.
- Every event or phenomenon has a cause or causes and that there is a reason for the form things take.

Big Ideas Sequence 1

Weather is a result of the condition and movement of their air. Patterns found in weather help us make predictions and identify seasons.

Evidence of Learning Specifications

Ask questions:

1. and investigate why changes in weather patterns take place.

MPS Science Curriculum Guide 12

Standard
A statement that Combines Science and Engineering Practices and Core Ideas to describe how students can show what they have learned

3D Foundations
The Practices, Core Ideas, and Crosscutting Concepts from *A Framework for K-12 Science Education* that were used to form the standards

Evidence of Learning Specifications (EoLS)
Standards and the 3-dimensions are used to develop EoLS, which describe what qualifies as evidence for students' proficiency.

Physical Science
SC22

Scope and Sequence
High School Physical Science

Physical science encompasses physical and chemical sub-processes that occur within systems. At the high school level, students gain an understanding of these processes at both the micro and macro levels through the intensive study of matter, energy, and forces. Students are expected to apply these concepts to real-world phenomena to gain a deeper understanding of causes, effects, and solutions for physical processes in the real world. The essential standards are those that every high school student is expected to know and understand. Plus standards in chemistry and physics are designed to extend the concepts learned in the essential standards to prepare students for entry level college courses. It is suggested to use the metric system within measurement.

Note:

- The standard number is designed for recording purposes and does not imply instructional sequence or importance.
- In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline.

Unit #	Unit	Standard
1	Matter and Energy in Systems	**Essential HS.P1U1.1** Develop and use models to explain the relationship of the structure of atoms to patterns and properties observed in the Periodic Table and describe how these models are revised with new evidence. **Essential HS.P1U1.2** Develop and use models for the transfer or sharing of electrons to predict the formation of ions, molecules, and compounds in both natural and synthetic processes.
		Essential HS.P1U1.3 Ask questions, plan, and carry out investigations to explore the cause and effect relationship between reaction rate factors.
		Essential HS.E2U1.15 Construct an explanation based on evidence to illustrate the role of nuclear fusion in the life cycle of a star.
2	Earth's Systems: Climate	**Essential HS.P4U1.10** Construct an explanation about the relationships among the frequency, wavelength, and speed of waves traveling in various media, and their applications to modern technology.
		Essential HS.E1U1.12 Develop and use models of the Earth that explains the role of energy and matter in Earth's constantly changing internal and external systems (geosphere, hydrosphere, atmosphere, biosphere).
		Essential HS.E1U1.11 Analyze and interpret data to determine how energy from the Sun affects weather patterns and climate.
3	Earth's Systems: Processes	**Essential HS.E1U1.12** Develop and use models of the Earth that explains the role of energy and matter in Earth's constantly changing internal and external systems (geosphere, hydrosphere, atmosphere, biosphere).
		Essential HS.E1U1.13 Evaluate explanations and theories about the role of energy and matter in geologic changes over time.

4	Space Systems and Formation	**Essential HS.P4U1.8** Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings.
		Essential HS.P4U1.8 Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings.
		Essential HS.E2U1.17 Construct an explanation of the origin, expansion, and scale of the universe based on astronomical evidence. **Essential HS.E2U1.15** Construct an explanation based on evidence to illustrate the role of nuclear fusion in the life cycle of a star.
5	Gravity's Role in Universal Movement	**Essential HS.P2U1.5** Construct an explanation for a field's strength and influence on an object (electric, gravitational, magnetic).
		Essential HS.E2U1.16 Construct an explanation of how gravitational forces impact the evolution of planetary motion, structure, surfaces, atmospheres, moons, and rings.
6	Application of Motion in Systems	**Essential HS.P3U1.6** Collect, analyze, and interpret data regarding the change in motion of an object or system in one dimension, to construct an explanation using Newton's Laws.
		Essential HS.P3U2.7 Use mathematics and computational thinking to explain how Newton's laws are used in engineering and technologies to create products to serve human ends.

Unit 1: Matter and Energy in Systems

P1: All matter in the Universe is made of very small particles.
E2: The Earth and our solar system are a very small part of one of many galaxies within the universe.

Instructional Sequence 1

Az Science Standard Essential HS.P1U1.1

Develop and use models to explain the relationship of the structure of atoms to patterns and properties observed in the Periodic Table and describe how these models are revised with new evidence.

Az Science Standard Essential HS.P1U1.2

Develop and use models for the transfer or sharing of electrons to predict the formation of ions, molecules, and compounds in both natural and synthetic processes.

CI P1 All matter in the Universe is made of very small particles.

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns.
- The repeating patterns of this table reflect patterns of outer electron states.

Science and Engineering Practices

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

Constructing Explanations and Designing Solutions:

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

Crosscutting Concepts

Energy and Matter:

- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Structure and Function:

- 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.
- 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

Patterns:

- 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.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

Matter is made up of tiny particles, atoms, which are composed of three subatomic particles: protons, neutrons, and electrons. These particles can be found in the nucleus or orbitals of the atom. The periodic table lists each known element which is identified by the number of protons the atom contains. The vertical columns on the periodic table identify elements with similar chemical and physical properties due to their shared electron configurations.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use models:

1. to illustrate the basic structure of an atom, including a positively charged nucleus which contains protons and neutrons sounded by negatively charged electrons.
2. to predict patterns of elements in the periodic table based on the structure of the atom including:
    a. electrons in the outermost energy level of atoms (i.e., valence electrons) and
    b. the number of protons in each element.
3. to predict an element's pattern of behavior based on both the attraction and repulsion between electrically charged particles and on the pattern of outermost electrons, which determine the typical reactivity of an atom (i.e., its tendency to lose or gain electrons).
    a. Transfer and sharing of electrons (covalent and ionic bonding) creates molecules and compounds.
    b. The arrangement of the periodic table can be used to predict chemical properties (i.e., electronegativity, ionization energy, electron affinity, atomic radius, melting point, metallic characteristics).

Construct an explanation:

1. on how the periodic table is used as a model to predict the relative properties of elements and how they will react based on their properties.

Instructional Sequence 2
Unit 1: Matter and Energy in Systems

Az Science Standard Essential HS.P1U1.3

Ask questions, plan, and carry out investigations to explore the cause and effect relationship between reaction rate factors.

CI P1 All matter in the universe is made of very small particles.

- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, that are matched by changes in kinetic energy.
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results.
- Ask questions that require relevant empirical evidence to answer.

Planning and Carrying Out Investigations:

- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Use investigations to gather evidence to support explanations or concepts.

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Crosscutting Concepts

Cause and Effect:

- 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.

Systems and System Models:

- 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.

Energy and Matter:

- 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.

- Energy drives the cycling of matter within and between systems.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Systems can be designed for greater or lesser stability.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 2

Matter changes form through chemical reactions based upon the interaction between outer electrons in atoms. This interaction always conserves mass and energy through the rearrangement of atoms and the absorption or release of energy.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions and carry out investigations to explore:

1. the cause and effect relationship between reaction rate factors and describe chemical reactions, i.e.,
   a. bonds that are broken during the reaction.
   b. bonds that are formed during the reaction.
2. how changing the concentration of one of the reacting components of the equilibrium system will change the rate of the reaction (forward or backward) until the forward and backward rates are again equal.
3. how the transformation of kinetic energy and/or potential energy from a chemical system interaction releases kinetic energy into the surroundings (or vice versa) by molecular collisions.
4. the Law of Conservation of Matter, or how the net change of energy within the system is the result of bonds that are broken and formed during the reaction. *(Note: This does not include calculating the total bond energy changes.)*

Instructional Sequence 3
Unit 1: Matter and Energy in Systems

Az Science Standard Essential HS.E2U1.15

Construct an explanation based on evidence to illustrate the role of nuclear fusion in the life cycle of a star.

CI E2 The Earth and our solar system are a very small part of one of many galaxies within the universe.

- The source of energy that the Sun and all stars radiate comes from nuclear reactions in their central cores.
- Nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases the energy seen as starlight.

Science and Engineering Practices

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Constructing Explanations and Designing Solutions:

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

Scale, Proportion, and Quantity:

- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.
- 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.

Energy and Matter:

- 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.
- Energy drives the cycling of matter within and between systems.

Using Science – U1

- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 3

Stars fill the universe, carrying out chemical reactions within their core and therefore producing the light we see. All stars form from clouds of gas and dust in space that are mostly made up of hydrogen. Gravity compresses this cloud and may lead to nuclear fusion if particles collide with enough energy . Most stars are average sized like the Sun but some are massive. All stars through the process of fusion rearrange matter into elements from helium to iron. However, only massive stars explode creating elements heavier than iron.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use and develop a model:

1. for fusion to illustrate that the fusion process releases energy and requires initial energy for the reaction to take place.
    a. for the Earth's Sun, hydrogen is its fuel and helium and energy are the products.
    b. the relative proportions of hydrogen to helium change as the sun ages.
    c. some of the energy released can be seen as starlight.

Construct explanation:

1. that describes the system of nuclear fusion and energy of stars (including electromagnetic and heat).
2. for the lifespan of the Sun, which, like all stars, is based primarily on its initial mass, and will burn out after approximately 10 billion years.

Unit 2: Earth's Systems: Climate

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

Instructional Sequence 1

Az Science Standard Essential HS.P4U1.10

Construct an explanation about the relationships among the frequency, wavelength, and speed of waves traveling in various media, and their applications to modern technology.

CI P4 The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments.
- All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).
- Photovoltaic materials emit electrons when they absorb light of a high-enough frequency.
- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.

Crosscutting Concepts

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Systems can be designed to cause a desired effect.

Energy and Matter:

- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors - as one factor changes, so does another in a regular way.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

All energy is stored and transferred between objects in the universe (matter). Energy can move in waves having both length and height (amplitude) determining its interaction with the matter it passes through. Different mediums affect its speed of travel across any distance. This energy can be measured and used to create images by digital processors to visualize data and find patterns.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Construct an explanation using evidence:

1. about how energy changes (i.e., frequency, wavelength, and speed of waves) traveling in various specified media (i.e., air, water), including:
   a. mathematical values for frequency, wavelength, and speed of waves.
2. about the application of wave properties in modern technology to:
   a. understand how structures have specific frequencies at which they resonate (i.e., vocal cords and musical instruments).
   b. predict the effect of change on one variable when observing the relationship between frequency and wavelength.
   c. understand the importance of the speed of light to our understanding of electromagnetic radiation.
   d. explain how types of electromagnetic radiation are manipulated by humans.

Instructional Sequence 2
Unit 2: Earth's Systems: Climate

Az Science Standard Essential HS.E1U1.12

Develop and use models of the Earth that explains the role of energy and matter in Earth's constantly changing internal and external systems (geosphere, hydrosphere, atmosphere, biosphere).

CI E1 The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics.
- These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- Develop a complex model that allows for manipulation and testing of a proposed process or system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Analyzing and Interpreting Data:

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

Crosscutting Concepts

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.
- 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.

Patterns:

- Empirical evidence is needed to identify patterns.

Energy and Matter:

- 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.

Cause and Effect:

- 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.
- Systems can be designed to cause a desired effect.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 2

Earth has an abundance of water, which has exceptional capacity to absorb, store and release large amounts of energy. Water's unique properties determine how it interacts with various energies and materials impacting all of Earth's systems.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate, and communicate information:

1. about the properties of water (i.e., heat capacity, density (each phase), transmit sunlight, expand upon freezing, dissolve materials, lower viscosities and melting points of rocks, and polar nature) and their effects on Earth materials and surface processes.

Use models to predict and analyze data:

1. about the effects of water's properties (i.e., high specific heat, evaporative cooling) on energy transfer, which cause patterns in temperature, movement of air, and movement and availability of water on Earth's surface (i.e., stream transportation and deposition, expansion of water as it freeze).
2. that explains the exchange of energy and matter through Earth's dynamic systems (i.e., geosphere, hydrosphere, atmosphere, biosphere).

Instructional Sequence 3
Unit 2: Earth's Systems: Climate

Az Science Standard Essential HS.E1U1.11

Analyze and interpret data to determine how energy from the Sun affects weather patterns and climate.

Note: In this course, climate change will be discussed through geological evidence and historical data. Human impact on climate is discussed in HS.E1U3.14 in Biology SC49.

CI E1 The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Weather, which varies from day to day and seasonally throughout the year, is the condition of the atmosphere at a given place and time.
- Climate is longer term and location sensitive; it is the range of a region's weather over 1 year or many years, and, because it depends on latitude and geography, it varies from place to place.
- The foundation for Earth's global climate system is the electromagnetic radiation from the Sun as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy's reradiation into space.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).
- Climate change can occur when certain parts of Earth's systems are altered.
- Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years.

Science and Engineering Practices

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Develop a complex model that allows for manipulation and testing of a proposed process or system.
- Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
- Evaluate the impact of new data on a working explanation of a proposed process or system.

Crosscutting Concepts

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.
- 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.

Patterns:

- 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.
- Empirical evidence is needed to identify patterns.

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Feedback (negative or positive) can stabilize or destabilize a system.

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Energy and Matter:

- 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.
- Energy drives the cycling of matter within and between systems

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.
- Phenomena that occurred in the past, such as rock changes or species evolution, can also be submitted to the process of hypothesis testing.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.

- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 3

Interactions between the Sun's radiation and Earth's Systems (hydrosphere, geosphere, biosphere, and atmosphere) make-up the planet's climate system. Changes in this system can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles on Earth and can be studied through geologic history using various methods. The geological record shows that changes to global and regional climate can be caused by interactions among changes in the Sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and organism activities.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use a model:

1. that displays the input, output, storage, and redistribution of energy from the Sun (i.e., changes in Earth's orbit and orientation of its axis, ocean circulation, atmospheric composition, volcanic activity, human activities) and how it affects weather and climate.

Analyze and interpret data:

1. to distinguish climate from weather.
2. to recognize how past climate changes were either:
    a. sudden changes caused by alterations in the atmosphere,
    b. longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis,
    c. or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen.
3. from climate system models (atmospheric, ocean and land) about the factors of energy flow (i.e., latitude, elevation, nearby water, ocean currents, topography, vegetation and prevailing winds) into and out of Earth's systems (i.e., atmosphere, hydrosphere, geosphere) and the patterns of all factors on the net effect in changing the climate.

Unit 3: Earth's Systems: Processes

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Instructional Sequence 1

Az Science Standard Essential HS.E1U1.12

Develop and use models of the Earth that explains the role of energy and matter in Earth's constantly changing internal and external systems (geosphere, hydrosphere, atmosphere, biosphere).

Az Science Standard Essential HS.E1U1.13

Evaluate explanations and theories about the role of energy and matter in geologic changes over time.

CI E1 The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- A model of Earth has a hot but solid inner core, a liquid outer core, a solid mantle, and crust.
- The top part of the mantle, along with the crust, forms structures known as tectonic plates.
- Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and the gravitational movement of denser materials toward the interior.
- The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it.
- Beneath the Earth's solid crust is a hot layer called the mantle. The mantle is solid when under pressure but melts (and is called magma) when the pressure is reduced.
- In some places there are cracks (or thin regions) in the crust which can allow magma to come to the surface, for example in volcanic eruptions.
- The Earth's crust consists of a number of solid plates which move relative to each other, carried along by movements of the mantle.
- Where plates collide, mountain ranges are formed and there is a fault line along the plate boundary where earthquakes are likely to occur and there may also be volcanic activity.
- Radioactive decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time.
- Continental rocks, which can be older than 4 billion years, are generally much older than rocks on the ocean floor, which are less than 200 million years old.
- Tectonic processes continually generate new ocean seafloor at ridges and destroy old seafloor at trenches.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Developing and Using Models:

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Asking Questions and Defining Problems:

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results.

Constructing Explanations and Designing Solutions:

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Crosscutting Concepts

Systems and System Models:

- 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.

Energy and Matter:

- 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.
- Energy drives the cycling of matter within and between systems.

Patterns:

- 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.

Cause and Effect:

- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.

Structure and Function:

- 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.

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model. Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

Earth is made up of layers which interact to create a dynamic system influencing many of Earth's fundamental processes. The driving force of change within this system is the movement of energy through matter by convection currents which affects the density of Earth matter, causing the movement of material.

Tectonic processes continue to shape Earth's surface and cause natural disasters like earthquakes, volcanic eruptions, and tsunamis through the processes of convergence, divergence, and transformation. These processes vary on a geologic scale happening at times very slowly while at others very quickly. Evidence of these changes are found in many sources.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate, and communicate information:

1. about the process of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move towards the center).
2. about how matter is cycled between the crust and the mantle at plate boundaries.
    a. Where plates are pushed together, cold crustal material sinks back into the mantle.
    b. Where plates are pulled apart, mantle material can be integrated into the crust, forming new rock (i.e., continually generate new ocean seafloor at ridges and destroy old seafloor at trenches).
3. explaining the role of energy and matter (i.e., weathering, erosion, volcanoes, tsunami, earthquake) in geologic changes (i.e., changes in extent or type of vegetation cover, configuration of continents resulting from tectonic activity over time).

Develop a model:

1. to identify and describe the components based on both seismic and magnetic evidence from Earth's interior (i.e., the pattern of the geothermal gradient or heat flow measurements) to illustrate and predict the relationship between the role of energy and matter in Earth's interior, thereby explaining the structure of Earth, including:
    a. Earth's interior in cross-section and radial layers (crust, magma, mantle, liquid outer core, solid inner core) determined by density.
    b. the plate activity in the outer part of the geosphere.
    c. the loss of heat at the surface of Earth as an output of energy.
    d. radioactive decay and residual thermal energy from the formation of Earth as a source of energy.
    e. identify causal links and feedback mechanisms between changes in the biosphere and changes in Earth's other systems.

Construct an explanation using multiple lines of evidence to show that:

1. the flow of matter in the mantle that causes crustal plates to move at fault lines.
2. the flow of matter in the liquid outer core that generates Earth's magnetic field, including evidence of polar reversals (e.g., seafloor exploration of changes in the direction of Earth's magnetic field).
3. the radial layers determined by density in the interior of Earth.
4. the addition of a significant amount of thermal energy released by radioactive decay in Earth's crust and mantle.

Unit 4: Space Systems and Formation

P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

Instructional Sequence 1

Az Science Standard Essential HS.P4U1.8

Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings.

CI P4 The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

Science and Engineering Practices

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Analyzing and Interpreting Data:

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
- Create a simple computational model or simulation of a designed device, process, or system.

Engaging in Argument from Evidence:

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

Crosscutting Concepts

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Systems and System Models:

- 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.
- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.

Scale, Proportion, and Quantity:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Systems can be designed for greater or lesser stability.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

The total amount of energy in any system determines what can occur. This energy is conserved and may transfer into, out of, or within the system, but the total amount always remains the same within the universe, being neither created or destroyed.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use a model (e.g., simple computer program, spreadsheet, simulation software package application) to:

1. define the boundaries of the system and the reference level for potential energy equals zero (the potential energy of the initial or final state does not have to be zero).
2. show the initial energies of the system's components (e.g., energy in fields, thermal energy, kinetic energy, energy stored in springs — all expressed as a total amount of Joules in each component), including a quantification in an algebraic description, and calculate the total initial energy of the system, including:

a. the energy flows in or out of the system, including a quantification in an algebraic description with flow into the system defined as positive.

b. the final energies of the system components, including a quantification in an algebraic description, to calculate the total final energy of the system.

3. analyze data to predict the maximum possible change in the energy of one component of the system for a given set of energy flows.

Engage in argument from evidence using mathematics:

1. to explain the fundamental principle and algebraic descriptions of the initial and final energy state of the system, or, that energy and matter cannot be created or destroyed.

Instructional Sequence 2
Unit 4: Space Systems and Formation

Az Science Standard Essential HS.P4U1.8

Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings.

CI P4 The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results.

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Engaging in Argument from Evidence:

- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.

Crosscutting Concepts

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy drives the cycling of matter within and between systems.

Cause and Effect:

- 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.

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.
- 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.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 2

Energy is measurable and on the macroscopic scale can be seen in motion, light, sound, thermal and chemical energy. This energy is transferred between potential and kinetic forms within or between systems especially when stored and released in chemical reactions.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use a model to:

1. identify what scientific principles provide the basis for the energy conversion design and the forms of energy that will be converted from one form to another (i.e., motion, sound, light, thermal energy) in the designed system (i.e., student developed model).
2. identify that sometimes when energy is converted from one form to another, some changes are irreversible (i.e., light to thermal).
3. identify losses of energy by the student-designed system (model) to the surrounding environment.

Engage in argument from evidence:

1. that energy is a quantitative property that depends on motion and interaction of matter and radiation within a system.
2. to demonstrate the cause and effect relationship between different forms of energy (i.e., thermal, radiant, chemical, motion, sound) showing that energy has many interchangeable forms and is conserved.

Instructional Sequence 3
Unit 4: Space Systems and Formation

Az Science Standard Essential HS.E2U1.17

Construct an explanation of the origin, expansion, and scale of the universe based on astronomical evidence.

Essential HS.E2U1.15

Construct an explanation based on evidence to illustrate the role of nuclear fusion in the life cycle of a star.

CI E2 The Earth and our solar system are a very small part of one of many galaxies within the Universe.

- There are billions of galaxies in the universe, almost unimaginably vast distances apart and perceived as moving rapidly away from each other.
- This apparent movement of galaxies may indicate that the universe is expanding from an event called a 'big bang', about 13.7 billion years ago.
- Nearly all observable matter in the universe is hydrogen or helium, which formed in the first minutes after the Big Bang.
- Elements other than these remnants of the Big Bang continue to form within the cores of stars.
- Nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases the energy seen as starlight.

Science and Engineering Practices

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Constructing Explanations and Designing Solutions:

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

Patterns:

- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.

Energy and Matter:

- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 3

The universe is unimaginably big and is getting bigger as galaxies move further apart, increasing the distances between them. This expansion originates from an event around 14 billion years ago termed "The Big Bang". The universe is filled with mostly hydrogen and helium which formed within moments of the Big Bang event . The rest of the elements in the periodic table were formed from star processes.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Analyze and interpret data:

1. about the patterns of astronomical evidence for the origin of the Universe, including how an expanding universe must have been smaller in the past and can be extrapolated back in time to a tiny size from which it expanded.

Develop a model:

1. to identify and describe the relevant components of the Sun's fusion processes, including:
   a. the composition of matter (hydrogen, helium and heavier elements) of stars.
   b. the hydrogen-helium ratio of stars and interstellar gases.

c. the redshift of the majority of galaxies and the redshift vs. distance relationship.

d. the existence of cosmic background radiation.

Construct an explanation:

1. that includes a description of how astronomical evidence from a variety of valid and reliable sources, including students' own investigations, theories, simulations, and peer review, to support the cosmic origin of the universe, which states that the universe is expanding (i.e., it was hotter and denser in the past (stability and change) and the entire visible universe emerged from a very tiny region and expanded).
2. helium and a small amount of other light nuclei (up to lithium) where formed from high energy collisions, starting from protons and neutrons, in the early universe before any stars existed.

Unit 5: Gravity's Role in Universal Movement

P2: Objects can affect other objects at a distance.
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

Instructional Sequence 1

Az Science Standard Essential HS.P2U1.5

Construct an explanation for a field's strength and influence on an object (electric, gravitational, magnetic).

Note: Emphasis is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).

CI P2 Objects can affect other objects at a distance.

- Newton's law of universal gravitation provides the mathematical models to describe and predict the effects of gravitational distant objects.
- Forces at a distance are explained by fields permeating space that can transfer energy through space.

Science and Engineering Practices

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.

Planning and Carrying Out Investigations:

- Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models.
- Use investigations to gather evidence to support explanations or concepts.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

Crosscutting Concepts

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Changes in systems may have various causes that may not have equal effects

Systems and System Models:

- 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.
- 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.

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

All objects with mass have proportional gravitational forces that affect other masses at a distance, inversely.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Analyze and interpret data from student-planned investigations:

1. that supports gravitational interactions in a system being attractive and dependent on both the masses of interacting objects and the relative magnitude and direction of the forces.

Use mathematical thinking:

1. to predict the cause and effect of gravity on the movement of distant objects.
2. to illustrate the orbital motion of objects in our solar system (i.e., moons orbit around planets, all objects within the solar system orbit the Sun).
3. to show that our solar system is one of many systems orbiting the center of the larger system of the Milky Way galaxy.

Construct an explanation:

1. to describe that gravity is a predominantly inward-pulling force (field) that causes smaller (less massive) objects in orbit around larger (more massive) objects.
2. that describes gravity as an attractive force between solar system and galaxy objects that increases with the mass of the interacting objects increases and decreases as the distances between objects increases.

Instructional Sequence 2
Unit 5: Gravity's Role in Universal Movements

Az Science Standard Essential HS.E2U1.16

Construct an explanation of how gravitational forces impact the evolution of planetary motion, structure, surfaces, atmospheres, moons, and rings.

Note: application of laws rather than memorization should be emphasized.

CI E2 The Earth and our solar system are a very small part of one of many galaxies within the Universe.

- The solar system consists of the Sun and a collection of objects of varying sizes and conditions—including planets and their moons—that are held in orbit around the Sun by its gravitational pull on them.
- Earth and the Moon, Sun, and planets have predictable patterns of movement.
- These patterns, which are explainable by gravitational forces and conservation laws, in turn explain many large-scale phenomena observed on Earth.
- Planetary motions around the Sun can be predicted using Kepler's three laws, which can be explained based on Newton's theory of gravity.
- Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

Science and Engineering Practices

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Analyzing and Interpreting Data:

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

Constructing Explanations and Designing Solutions:

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

Crosscutting Concepts

Systems and System Models:

- 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.
- 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.

Scale, Proportion, and Quantity:

- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- 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).

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 2

The movement of planets are affected by gravity (Newton's Law of Universal Gravitation) and explained using Kepler's three laws, which state that planets move in elliptical orbits and that the time a planet takes to sweep an area in its orbit remains the same regardless of distance due to gravity's decreasing influence as distance increases.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use a model:

1. using Kepler's three laws to show that in a system of masses interacting via gravitational forces, larger masses experience and exert proportionally larger gravitational forces.

Construct an explanation by analyzing data and mathematical evidence:

1. using Kepler's three laws at various scales that predicts orbital motion through the direction of gravitational forces and masses of interacting objects observed in the universe.
    a. All planets move about the Sun in elliptical orbits, having the Sun as one of the foci.
    b. A line that connects a planet to the Sun sweeps out equal areas in equal times.
    c. The square of the period of any planet is proportional to the cube of the semimajor axis of its orbit.

MESA PUBLIC SCHOOLS
MESA, ARIZONA

Unit 6: Application of Motion in Systems

P3: Changing the movement of an object requires a net force to be acting on it.

Instructional Sequence 1

Az Science Standard Essential HS.P3U1.6

Collect, analyze, and interpret data regarding the change in motion of an object or system in one dimension, to construct an explanation using Newton's Laws.

CI P3 Changing the movement of an object requires a net force to be acting on it.

- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
- In any system, total momentum is always conserved.
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Use investigations to gather evidence to support explanations or concepts.

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Crosscutting Concepts

Cause and Effect:

- 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.
- Changes in systems may have various causes that may not have equal effects.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- 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).

Systems and System Models:

- 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.
- 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.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

An object's motion in a straight line and single direction can be predicted using the relationship between mass, acceleration, and force. The momentum within or between systems is conserved between interacting objects.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Plan and carry out investigations:

1. to identify the phenomenon during a student-planned investigation and provide evidence that the change in an object's motion:

a. has balanced or unbalanced forces acting on the object.

b. is algebraically related to the mass of the object.

Analyze and Interpret data using mathematical and computational thinking:

1. about Newton's laws on force, mass, acceleration, and momentum to predict their effects on the motion of objects in a system.
2. to support the claim that the momentum of the system is the same before and after the interaction between the objects in the system, so that momentum of the system is constant.

Instructional Sequence 2
Unit 6: Application of Motion in Systems

Az Science Standard Essential HS.P3U2.7

Use mathematics and computational thinking to explain how Newton's laws are used in engineering and technologies to create products to serve human ends.

CI P3 Changing the movement of an object requires a net force to be acting on it.

- The application of science in making new materials is an example of how scientific knowledge has led advances in technology and provided engineers with a wider choice in designing constructions.
- At the same time technological advances have helped scientific developments by improving instruments for observation and measuring, automating processes that might otherwise be too dangerous or time consuming to undertake, and particularly through the provision of computers.
- Thus, technology aids scientific advances which in turn can be used in designing and making things for people to use.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design.
- Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.

Planning and Carrying Out Investigations:

- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts.
- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Analyzing and Interpreting Data:

- Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

Constructing Explanations and Designing Solutions:

- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects.
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and trade-off considerations.

Crosscutting Concepts

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- 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).

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.

Using Science – U2

- Science, engineering, and technology are closely inter-connected. The application of science in making new materials is an example of how scientific knowledge has led advances in technology and provided engineers with a wider choice in designing constructions.
- Technological advances have helped scientific developments by improving instruments for observation and measuring, automating processes that might otherwise be too dangerous or time consuming to undertake, and particularly through the provision of computers.
- Technology aids scientific advances which in turn can be used in designing and making things for people to use.
- Often in the past technological products have been developed empirically in advance of scientific ideas.

Big Ideas Sequence 2

Technology is used to help further science and aide in designing and constructing tools for use by society.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Plan and carry out an investigation:

1. to show how a more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a less massive object has a correspondingly larger acceleration.

Use mathematics and computational thinking:

1. to design a solution (e.g., an object, tool, process, or system) to a problem involving a collision of two objects, and identify and describe:
   a. the components within the system that are involved in the collision,

b. the force that will be exerted by the first object on the second object,

c. how Newton's third law will be applied to design the solution to the problem, and

d. the technologies (i.e., any human-made material or device) that will be used in the solution.

Analyze data:

1. to describe the given criteria and constraints and how they will be taken into account when designing the solution (i.e., cost, mass and speed of objects, time, materials).
2. using knowledge of Newton's third law to systematically determine how well the design solution meets the criteria and constraint.

Earth and Space Science SC33

Scope and Sequence
High School Earth and Space Science

Earth and Space Science encompass processes that occur on Earth while also addressing Earth's place within the solar system and galaxy. At the high school level, students gain an understanding of these processes through a wide scale: unimaginably large to invisibly small. Earth and Space Sciences, more than any other discipline, are rooted in other scientific disciplines. Students, through the close study of Earth and space, will find clear applications for their knowledge of gravitation, energy, magnetics, cycles, and biological processes. Educators should use the "connections" designations within these standards to assist students in making connections between scientific disciplines. Additionally, students are expected to apply these concepts to real-world phenomena to gain a deeper understanding of causes, effects, and solutions for physical processes in the real world. The essential standards are those that every high school student is expected to know and understand. Plus standards in Earth and Space Science are designed to extend the concepts learned in the essential standards to prepare students for entry level college courses.

Note:

- The standard number is designed for recording purposes and does not imply instructional sequence or importance.
- In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline.

Unit #	Unit	Standard
1	Space Systems: The Universe	**Essential HS.E2U1.17** Construct an explanation of the origin, expansion, and scale of the universe based on astronomical evidence. **Plus HS+E.E2U1.16** Obtain, evaluate, and communicate information about patterns of size and scale of our solar system, our galaxy, and the universe. **Plus HS+E.E2U2.17** Obtain, evaluate, and communicate the impact of technology on human understanding of the formation, scale, and composition of the universe.
		Essential HS.P4U1.10 Construct an explanation about the relationships among the frequency, wavelength, and speed of waves traveling in various media, and their applications to modern technology.
2	Space Systems: Stars	**Essential HS.E2U1.15** Construct an explanation based on evidence to illustrate the role of nuclear fusion in the life cycle of a star. **Plus HS+E.E2U1.12** Obtain, evaluate, and communicate scientific information about the way stars, throughout their stellar stages, produce elements and energy.
3	Space Systems: Gravity and Movement	**Plus HS+E.E2U1.13** Analyze and interpret data showing how gravitational forces are influenced by mass, and the distance between objects.

		Plus HS+E.E2U1.15 Obtain, evaluate, and communicate information on how the nebular theory explains solar system formation with distinct regions characterized by different types of planetary and other bodies.
		Essential HS.E2U1.16 Construct an explanation of how gravitational forces impact the evolution of planetary motion, structure, surfaces, atmospheres, moons, and rings. **Plus HS+E.E2U1.14** Use mathematics and computational thinking to explain the movement of planets and objects in the solar system.
4	Earth Systems: Materials	**Plus HS+E.E1U1.7** Engage in argument from evidence of ancient Earth materials, meteorites and other planetary surfaces to explain Earth's formation and early history. **Essential HS.E1U1.13** Evaluate explanations and theories about the role of energy and matter in geologic changes over time. **Essential HS.L4U1.28** Gather, evaluate, and communicate multiple lines of empirical evidence to explain the mechanisms of biological evolution.
5	Earth Systems: Internal Processes	**Essential HS.E1U1.13** Evaluate explanations and theories about the role of energy and matter in geologic changes over time. **Plus HS+E.E1U1.6** Obtain, evaluate, and communicate information of the theory of plate tectonics to explain the differences in age, structure, and composition of Earth's crust. **Plus HS+E.E1U1.8** Develop and use models to illustrate how Earth's internal and surface processes operate over time to form, modify and recycle continental and ocean floor features. **Essential HS.P2U1.5** Construct an explanation for a field's strength and influence on an object (electric, gravitational, magnetic).
6	Earth Systems: Water & Energy	**Plus HS+E.E1U1.5** Obtain, evaluate, and communicate information on the effect of water on Earth's materials, surface processes, and groundwater systems. **Plus HS+E.E1U1.1** Construct an explanation based on evidence for how the Sun's energy transfers between Earth's systems. **Essential HS.E1U1.12** Develop and use models of the Earth that explains the role of energy and matter in Earth's constantly changing internal and external systems (geosphere, hydrosphere, atmosphere, biosphere).
		Essential HS.E1U1.11 Analyze and interpret data to determine how energy from the Sun affects weather patterns and climate.
7	Earth Systems: Changing Earth	**Plus HS+E.E1U1.2** Develop and use models to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate **Plus HS+E.E1U1.3** Analyze geoscience data and the results from global climate models to make evidence-based predictions of current rate and scale of global or regional climate changes. **Plus HS+E.E1U1.4** Analyze and interpret geoscience data to make the claim that dynamic interactions with Earth's surface can create feedbacks that causes changes to other Earth systems.

		Plus HS+E.E1U3.11 Develop and use a quantitative model to illustrate the relationship among Earth systems and the degree to which those relationships are being modified due to human activity.
8	Earth Systems: Resources	**Plus HS+E.E1U3.9** Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **Essential HS.E1U3.14** Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other. **Essential HS.L2U3.18** Obtain, evaluate, and communicate about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem.
		Plus HS+E.E1U3.10 Ask questions, define problems, and evaluate a solution to a complex problem, based on prioritized criteria and tradeoffs, that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. **Essential HS.L2U3.18** Obtain, evaluate, and communicate about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem.

MESA PUBLIC SCHOOLS MESA, ARIZONA

Unit 1: Space Systems: The Universe

E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

Instructional Sequence 1

Az Science Standard Essential HS.E2U1.17

Construct an explanation of the origin, expansion, and scale of the universe based on astronomical evidence.

Az Science Standard Plus HS+E.E2U1.16

Obtain, evaluate, and communicate information about patterns of size and scale of our solar system, our galaxy, and the universe.

Az Science Standard Plus HS+E.E2U2.17

Obtain, evaluate, and communicate the impact of technology on human understanding of the formation, scale, and composition of the universe.

CI E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

- There are billions of galaxies in the universe, almost unimaginably vast distances apart and perceived as moving rapidly away from each other.
- This apparent movement of galaxies indicates that the universe is expanding from an event called a 'big bang', about 13.7 billion years ago.
- Nearly all observable matter in the universe is hydrogen or helium, which formed in the first minutes after the Big Bang.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.
- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Constructing Explanations and Designing Solutions:

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Crosscutting Concepts

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Patterns:

- 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.

Using Science – U1

- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Using Science – U2

- Often in the past technological products have been developed empirically in advance of scientific ideas.
- Technological advances have helped scientific developments by improving instruments for observation and measuring, automating processes that might otherwise be too dangerous or time consuming to undertake, and particularly through the provision of computers.

Big Ideas Sequence 1

Galaxies are moving apart at accelerating rates, leading scientists to theorize that the universe is expanding due to the Big Bang. Other evidence, including cosmic background radiation and hydrogen/helium amounts, confirm this model.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate and communicate:

1. patterns of evidence (i.e., the composition of stars; hydrogen-helium ratio of starts and interstellar gases; redshift; existence of cosmic background radiation) about the scale of the Universe and the motions of galaxies including:
   a. an expanding universe must have been smaller in the past and can be extrapolated back in time to a tiny size from which it expanded.
2. the technology used in order to obtain evidence of the expansion and scale of the universe.

Construct an explanation that describes:

1. the current theory for the origin of the universe and how astronomical evidence from numerous sources is used collectively to support that the universe is expanding and thus was hotter and denser in the past, and so the entire visible universe emerged from a very tiny region. Evidence includes:
   a. Redshifts indicate that an object is moving away from the observer, thus the observed redshift for most galaxies and the redshift vs. distance relationship is evidence that the universe is expanding.

b. The observed background cosmic radiation and the ratio of hydrogen to helium have been shown to be consistent with a universe that was very dense and hot a long time ago and evolved through different stages as it expanded and cooled (i.e., the formation of nuclei from colliding protons and neutrons predicts the hydrogen-helium ratio *(numbers not expected from students)*, later formation of atoms from nuclei plus electrons, background radiation was a relic from that time).

Instructional Sequence 2
Unit 1: Space Systems: The Universe

Az Science Standard Essential HS.P4U1.10

Construct an explanation about the relationships among the frequency, wavelength, and speed of waves traveling in various media, and their applications to modern technology.

Az Science Standard Essential HS.E2U1.17

Construct an explanation of the origin, expansion, and scale of the universe based on astronomical evidence.

CI P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
- All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light.

CI E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

- The next nearest star [from the Sun] is much further away than the distance of the furthest planet, Neptune.
- The distances between and within galaxies are so great that they are measured in 'light years', the distance that light can travel in a year.

Science and Engineering Practices

Constructing Explanations and Designing Solutions:

- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Crosscutting Concepts

Patterns:

- 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.

Scale, Proportion, and Quantity:

- Patterns observable at one scale may not be observable or exist at other scales.

Structure and Function:

- 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

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

Big Ideas Sequence 1

Radiation is broken up into an electromagnetic spectrum that has predictable patterns. This information can be used to examine distance, light, and motion across the universe.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Construct an explanation that describes:

1. patterns in frequency, wavelength and speed of waves in relation to distance, light and motion of galaxies.
2. distances between planets, stars, moons and other bodies in the universe (i.e., next nearest star, furthest planet of Neptune) using different scales (i.e., lightyears).

Use mathematics and computational thinking:

1. to apply quantitative values of wave properties in modern technology to:
   a. understand how structures have specific frequencies at which they resonate (i.e., astronauts using frequencies to remotely sense Earth's surface and atmosphere).
   b. predict the effect of change on one variable when observing the relationship between frequency and wavelength.
   c. understand the importance of the speed of light to our understanding of electromagnetic radiation and explain how types of electromagnetic radiation (i.e., ultraviolet, X-rays, gamma rays) are manipulated by humans (i.e., NASA satellites track different wavelengths of radiation to gather information about their sources).

Unit 2: Space Systems: Stars

E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

Instructional Sequence 1

Az Science Standard Essential HS.E2U1.15

Construct an explanation based on evidence to illustrate the role of nuclear fusion in the life cycle of a star.

Az Science Standard Plus HS+E.E2U1.12

Obtain, evaluate, and communicate scientific information about the way stars, throughout their stellar stages, produce elements and energy.

CI E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

- Nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases the energy seen as starlight.
- Heavier elements are produced when certain massive stars achieve a supernova stage and explode.
- Elements other than these remnants of the Big Bang continue to form within the cores of stars.
- Our Sun is one of many stars that make up the Universe, essentially made of hydrogen.
- The source of energy that the Sun and all stars radiate comes from nuclear reactions in their central cores.

Science and Engineering Practices

Constructing Explanations and Designing Solutions:

- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Obtaining, Evaluating, and Communicating Information:

- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.

Crosscutting Concepts

Structure and Function:

- 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.

Systems and System Models:

- 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.

Energy and Matter:

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Using Science – U1

- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

Big Ideas Sequence 1

Elements and energy are created through nuclear fusion inside of stars. As elements are depleted, fusion will change and the star will go through stages in its life cycle, resulting in different types of stars, elements, and other phenomena.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate and communicate:

1. how observations of distant stars provide insight on various stages of development.
2. about nuclear processes that produce elements and energy throughout a star's stellar stages.

Construct an explanation that:

1. describes the structure of a star and the role of nuclear fusion in the star's core to release energy in the form of radiation.
2. that accounts for the production of all atomic nuclei and elements in the universe.
    a. more massive elements up to iron are produced by cores of stars by nuclear fusion.
    b. supernova explosions (death) of massive stars are the mechanisms by which elements more massive than iron are produced.
3. uses evidence to illustrate and model (i.e., physical, mathematical, computer models can be used to simulate systems and interactions) the lifespan of a star, including:
    a. Hydrogen as the Sun's fuel.
    b. Helium and energy as the products of fusion processes in the Sun.
    c. That the Sun, like all stars, has a life span based primarily on its initial mass, and that the Sun's lifespan is about 10 billion years.
    d. The Hertzsprung-Russell Diagram.

Unit 3: Space Systems: Gravity and Movement

E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

Instructional Sequence 1

Az Science Standard Plus HS+E.E2U1.13

Analyze and interpret data showing how gravitational forces are influenced by mass and the distance between objects.

Az Science Standard Plus HS+E.E2U1.15

Obtain, evaluate, and communicate information on how the nebular theory explains solar system formation with distinct regions characterized by different types of planetary and other bodies.

CI E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

- This system appears to have formed from a disk of dust and gas, drawn together by gravity.
- The solar system consists of the Sun and a collection of objects of varying sizes and conditions—including planets and their moons—that are held in orbit around the Sun by its gravitational pull on them.

Science and Engineering Practices

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.

Obtaining, Evaluating, and Communicating Information:

- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Crosscutting Concepts

Cause and Effect:

- 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.
- Changes in systems may have various causes that may not have equal effects.

Patterns:

- Mathematical representations are needed to identify some patterns
- Empirical evidence is needed to identify patterns.

Systems and System Models:

- 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.

Structure and Function:

- 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.

Using Science – U1

- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.

Big Ideas Sequence 1

Gravity is an attractive force based on the mass of the object and the distance between objects. The early solar system formed due to gravity bringing together matter to form stars and planets. The spin and motion of these objects influenced their structure and orbits with the solar system.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Analyze and interpret data to:

1. identify how changing mass or distance will affect gravitational pull.
    a. Increases with the mass of the interacting objects increases.
    b. Decreases as the distances between objects increases.
2. describe that gravity is a predominantly inward-pulling force that can keep smaller (less massive) objects in orbit around larger (more massive) objects.

Obtain, evaluate, and communicate information that describes:

1. the processes that lead to the patterns (Nebular Theory) we see in our solar system's structure, including:
    a. planets all rotate in the same direction.
    b. all planets orbit within six degrees of a common plane.
    c. all terrestrial planets, which are those within the Asteroid Belt, are rocky, while those planets (Jovian) outside it are gaseous.

Instructional Sequence 2
Unit 3: Space Systems: Gravity & Movement

Az Science Standard HS.E2U1.16

Construct an explanation of how gravitational forces impact the evolution of planetary motion, structure, surfaces, atmospheres, moons, and rings.

Az Science Standard Plus HS+E.E2U1.14

Use mathematics and computational thinking to explain the movement of planets and objects in the solar system.

CI E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

- Earth and the Moon, Sun, and planets have predictable patterns of movement.
- These patterns, which are explainable by gravitational forces and conservation laws, in turn explain many large-scale phenomena observed on Earth.
- Gravity holds Earth in orbit around the Sun, and it holds the Moon in orbit around Earth.
- Planetary motions around the Sun can be predicted using Kepler's three empirical laws, which can be explained based on Newton's theory of gravity.
- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the Sun. *(Note: application of laws rather than memorization should be emphasized.)*

Science and Engineering Practices

Constructing Explanations and Designing Solutions:

- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Using Mathematics and Computational Thinking:

- Create a simple computational model or simulation of a designed device, process, or system.

Crosscutting Concepts

Patterns:

- 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.

Structure and Function:

- 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.

Cause and Effect:

- 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.
- Changes in systems may have various causes that may not have equal effects.

Scale, Proportion, Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- 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).

Using Science – U1

- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.

Big Ideas Sequence 2

The motions and orbits of objects within the solar system are governed by the gravitational interactions between the objects. The motions can be understood and predicted using the laws of gravity, Newton's Laws of Motion, Kepler's Laws of Planetary Motion, and Nebular Theory.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use mathematics and computational thinking:

1. show quantitative patterns that provide evidence of elliptical orbital motion including planets, moons, or human-made spacecraft; each of which depicts a revolving body's eccentricity, $e = f/d$, where f is the distance between foci of an ellipse, and d is the ellipse's major axis length (Kepler's first law of planetary motion).

Construct explanations to understand:

1. why smaller objects orbit around larger objects in predictable patterns.
2. how gravitational forces cause planets' structures to be spherical, hold atmospheres, and have orbiting bodies, due to:
   a. Gravity affects planetary motion.
   b. Gravity causes large structures to become spherical.
   c. Surface processes are affected by gravity (i.e., erosion, weathering, and deposition).
   d. A planet's gravity holds other matter in place (i.e., its atmosphere, its rings and its moons).

Unit 4: Earth System: Materials

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.
L4: The unity and diversity of organisms, living and extinct, is the result of evolution.

Instructional Sequence 1

Az Science Standard Plus HS+E.E1U1.7

Engage in argument from evidence of ancient Earth materials, meteorites and other planetary surfaces to explain Earth's formation and early history.

Az Science Standard Essential HS.E1U1.13

Evaluate explanations and theories about the role of energy and matter in geologic changes over time.

Az Science Standard Essential HS.L4U1.28

Gather, evaluate, and communicate multiple lines of empirical evidence to explain the mechanisms of biological evolution.

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Radioactive decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geologic time.
- Although active geological processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock records on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years.
- Studying these objects can provide info about Earth's formation and early history.

CI L4: The unity and diversity of organisms, living and extinct, is the result of evolution.

- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species.
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or too drastic, the opportunity for the species' evolution is lost.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Engaging in Argument from Evidence:

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.

Crosscutting Concepts

Patterns:

- Mathematical representations are needed to identify some patterns

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Systems and System Models:

- 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.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- Patterns observable at one scale may not be observable or exist at other scales.

Using Science – U1

- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Phenomena that occurred in the past, such as rock changes or species evolution, can also be submitted to the process of hypothesis testing.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.
- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

Big Ideas Sequence 1

Evidence from the solar system can be used to reconstruct the early history of Earth. Radiometric dating and isotope content in rocks with crater records on Earth's surface help support the conclusion of Earth's age. Evidence of Earth's formation can be verified due to the study of the stratification of Earth's layers. The impact of the size and composition of objects from the solar system helped shape Earth's past and current surface and climate.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate, and communicate information and scientific reasoning to:

1. support the claim that the radiometric age of lunar rocks, Earth's oldest rocks, and meteorites accurately explains the age of Earth's crust from 4.6 billion years ago.

2. observe the pattern in size and distribution of impact craters on the surface of Earth and on the surfaces of solar system objects (i.e., the Moon, Mercury, and Mars);
    a. Explain how early Earth was bombarded by impacts in the same way other objects in the solar system were, but changes from erosion and plate tectonics on Earth have destroyed much of the evidence of this bombardment, explaining the relative scarcity of impact craters on Earth.
3. describe the composition of solar system objects.
4. describe the activity of plate tectonic processes, such as volcanism, and surface processes, such as erosion, operating on Earth.

Engage in arguments from evidence that:

1. the events of Earth's history can be organized from mass extinctions, evolution of life, and major geological events into a geological time scale.

Unit 5: Earth Systems: Internal Processes

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.
P2: Objects can affect other objects at a distance.

Instructional Sequence 1

Az Science Standard HS.E1U1.13

Evaluate explanations and theories about the role of energy and matter in geologic changes over time.

Az Science Standard Plus HS+E.E1U1.6

Obtain, evaluate, and communicate information of the theory of plate tectonics to explain the differences in age, structure, and composition of Earth's crust.

Az Science Standard Plus HS+E.E1U1.8

Develop and use models to illustrate how Earth's internal and surface processes operate over time to form, modify and recycle continental and ocean floor features.

Az Science Standard Essential HS.P2U1.5

Construct an explanation for a field's strength and influence on an object (electric, gravitational, magnetic).

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Beneath the Earth's solid crust is a hot layer called the mantle.
- The mantle is solid when under pressure but melts (and is called magma) when the pressure is reduced.
- In some places there are cracks (or thin regions) in the crust which can allow magma to come to the surface, for example in volcanic eruptions.
- The top part of the mantle, along with the crust, forms structures known as tectonic plates.
- Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and the gravitational movement of denser materials toward the interior.
- Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust.
- The Earth's crust consists of a number of solid plates which move relative to each other, carried along by movements of the mantle.
- Where plates collide, mountain ranges are formed and there is a fault line along the plate boundary where earthquakes are likely to occur and there may also be volcanic activity.
- Tectonic processes continually generate new ocean seafloor at ridges and destroy old seafloor at trenches.
- Continental rocks, which can be older than 4 billion years, are generally much older than rocks on the ocean floor, which are less than 200 million years old.
- The Earth's surface changes slowly over time, with mountains being eroded by weather, and new ones produced when the crust is forced upwards.

CI P2: Objects can affect other objects at a distance.

- A magnet, for example, can attract or repel another magnet and both play equal parts.
- Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Developing & Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Crosscutting Concepts

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Structure and Function:

- 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.

Energy and Matter:

- 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.
- Energy drives the cycling of matter within and between systems.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Patterns:

- 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.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Changes in systems may have various causes that may not have equal effects.

Using Science – U1

- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Phenomena that occurred in the past, such as rock changes or species evolution, can also be submitted to the process of hypothesis testing.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.
- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

Big Ideas Sequence 1

Earth is segmented into multiple layers of materials, including the semi-solid mantle. The mantle is heated from Earth's hot metallic core and rises, due to convection, up to the crust. This process drives crustal and plate movement around Earth. These plates can collide and form mountains and volcanoes as denser, oceanic crust subducts back into the mantle, is melted, and recycled. New crust is also created at ocean ridges, as underwater volcanic activity creates new ocean crust. Continental crust is less dense, so will not subduct and melt, and is thus typically made of very old rock. This rock can be worn down by water, wind, ice, and gravity, resulting in a constantly changing landscape on the surface of Earth.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate, communicate information to:

1. explain how sedimentary, metamorphic, and igneous rocks can change into one another.
2. identify and describe the components of Earth's interior based on both seismic and magnetic evidence (i.e., the pattern of the geothermal gradient or heat flow measurements), including:
    a. cross-sections and radial layers (crust, magma, mantle, liquid outer core, solid inner core) determined by density.
    b. the plate activity in the geosphere.
    c. energy sources from radioactive decay and residual thermal energy from the formation of Earth.
    d. the loss of heat at the surface of Earth as an output of energy.
    e. the process of convection that causes hot matter to rise (move away from the center) and cool matter to fall (move toward the center).
3. understand how several layers of Earth exist and support the theory of plate tectonics through the use of computer models.

4. the distribution of seafloor structures (i.e., trenches, ridges, and changes in magnetization of the seafloor)and rock ages provide evidence that continental rocks are older than seafloor rocks.

Develop and use models to predict:

1. how mantle convection creates the energy to moves plates, creating divergent, convergent, and transform boundaries, and how these boundaries create, change, and recycle mountains, volcanoes, mid-ocean ridges, and other geologic structures.
2. how wind, water, ice, and gravity can change Earth's surface and create different geologic features.

Construct and revise an explanation:

1. based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future to describe the cycling of matter caused by thermal convection in Earth's interior, including:
   a. Energy released by radioactive decay in Earth's crust and mantle, along with residual thermal energy from the formation of Earth, provide energy that drives the flow of matter in the mantle.
   b. Thermal energy is released at the surface of Earth as new crust is formed and cooled.
   c. The sinking of this cold, dense crust back into the mantle along with the flow of matter by convection in the solid mantle exerts forces on crustal plates that then move, producing tectonic activity.
   d. This tectonic activity either pushes plates together, causing cold crustal material to sink back into the mantle, or pulls plates apart, causing mantle material to be integrated into the crust, forming new rock.
   e. The flow of matter by convection in the liquid outer core generates Earth's magnetic field, including evidence of polar reversals (i.e., seafloor exploration of changes in the direction of Earth's magnetic field).

Unit 6: Earth Systems: Water and Energy

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

Instructional Sequence 1

Az Science Standard Plus HS+E.E1U1.5

Obtain, evaluate, and communicate information on the effect of water on Earth's materials, surface processes, and groundwater systems.

Az Science Standard Plus HS+E.E1U1.1

Construct an explanation based on evidence for how the Sun's energy transfers between Earth's systems.

Az Science Standard Essential HS.E1U1.12

Develop and use models of the Earth that explains the role of energy and matter in Earth's constantly changing internal and external systems (geosphere, hydrosphere, atmosphere, biosphere).

Essential HS.P4U1.10

Construct an explanation about the relationships among the frequency, wavelength, and speed of waves traveling in various media, and their applications to modern technology.

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics.
- These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.
- The foundation for Earth's global climate system is the electromagnetic radiation from the Sun as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems and this energy's reradiation into space.

CI P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).

Science and Engineering Practices

Developing & Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Constructing Explanations and Designing Solutions:

- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Obtaining, Evaluating, and Communicating Information:

- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Crosscutting Concepts

Patterns:

- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Cause and Effect:

- 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.
- Changes in systems may have various causes that may not have equal effects.

Systems and System Models:

- 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.
- 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.
- 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.

Energy and Matter:

- 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.
- Energy drives the cycling of matter within and between systems.
- The total amount of energy and matter in closed systems is conserved.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Using Science – U1

- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.

Big Ideas Sequence 1

Energy from the Sun heats Earth and provides almost all the energy for processes on the planet. The foundation for Earth's global climate system is the electromagnetic radiation from the Sun as well as its reflection, absorption, storage, and redistribution among Earth's systems. This energy is cycled through the environment via conduction, convection, and radiation. Different materials, such as water, can cycle through the environment and carry energy with it.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate, and communicate information to explain:

1. The pattern of water cycling throughout each of Earth's systems (hydrosphere, atmosphere, biosphere, geosphere).
2. the properties of water (i.e., heat capacity, density (each phase), transmit sunlight, expand upon freezing, dissolve materials, lower viscosities and melting points of rocks, and polar nature) and its effects on Earth materials and surface processes.

Develop and use models to:

1. show the effects of water's properties (i.e., high specific heat, evaporative cooling) on energy transfer, which cause patterns in temperature, movement of air, and movement and availability of water on Earth's surface (i.e., stream transportation and deposition, expansion of water as it freeze).
2. that explains the exchange of energy and matter through Earth's dynamic systems (i.e., geosphere, hydrosphere, atmosphere, biosphere).

Construct explanations to model:

1. the specific cause and effect relationships between the factors that cause energy to flow into and out of Earth's systems.
2. how energy from the Sun (electromagnetic radiation) flows and materials on Earth cycle due to energy transfer and conservation of matter.

Instructional Sequence 2
Unit 6: Earth Systems: Water and Energy

Az Science Standard Essential HS.E1U1.11

Analyze and interpret data to determine how energy from the Sun affects weather patterns and climate.

Az Science Standard Plus HS+E.E1U1.1

Construct an explanation based on evidence for how the Sun's energy transfers between Earth's systems.

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Weather, which varies from day to day and seasonally throughout the year, is the condition of the atmosphere at a given place and time.
- Climate is longer term and location sensitive; it is the range of a region's weather over 1 year or many years, and, because it depends on latitude and geography, it varies from place to place.
- The foundation for Earth's global climate system is the electromagnetic radiation from the sun as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's reradiation into space.
- The geological record shows that changes to global and regional climate can be caused by interactions among changes in the Sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles.

Science and Engineering Practices

Analyzing and Interpreting Data:

- Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.
- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.

Crosscutting Concepts

Patterns:

- 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.

Systems and System Models:

- 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.
- 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.
- 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.

Energy and Matter:

- 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.
- Energy drives the cycling of matter within and between systems.

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.

Big Ideas Sequence 2

Weather is the current atmospheric conditions based on the energy in the atmosphere and the type of air and water amounts in a location. Weather is a short-term change, which can cause a variety of temperature and precipitation patterns. Climate is long term and based on a variety of factors such as location, water, winds and topography. Climate has also changed in the past due to a variety of long-term factors, such as Earth's orbit and rotation, Solar variance, volcanic activity along with other factors related to changing the energy on the planet.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Analyze and interpret data:

1. from models of the system (student defined) that display the input and output of energy from the Sun and how it affects weather and climate, including:
   a. changes in Earth's orbit and the orientation of its axis
   b. in the geosphere (i.e., tectonic activity, volcanic activity).
   c. in the hydrosphere (i.e., ocean circulation, glaciation).
   d. in the atmosphere (i.e., composition (including amount of water vapor and CO_2), circulation).
   e. in the biosphere (i.e., changes in extent or type of vegetation cover, human activities).
2. from weather patterns and their relationship to how cold and warm air masses interact at a location according to the density and water moisture content.
3. of factors (latitude, water, wind, and topography) that influence a location's climate patterns (i.e., the net effect of all competing factors in changing the climate).

Unit 7: Earth Systems: Changing Earth

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Instructional Sequence 1

Az Science Standard Plus HS+E.E1U1.2

Develop and use models to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Az Science Standard Plus HS+E.E1U1.3

Analyze geoscience data and the results from global climate models to make evidence-based predictions of current rate and scale of global or regional climate changes.

Az Science Standard Plus HS+E.E1U1.4

Analyze and interpret geoscience data to make the claim that dynamic interactions with Earth's surface can create feedbacks that causes changes to other Earth systems.

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years.
- A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts.
- Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- Global climate models are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history.

Science and Engineering Practices

Analyzing and Interpreting Data:

- Evaluate the impact of new data on a working explanation of a proposed process or system.
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data
- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.

Developing and Using Models:

- Design a test of a model to ascertain its reliability.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Crosscutting Concepts

Patterns:

- Empirical evidence is needed to identify patterns.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Feedback (negative or positive) can stabilize or destabilize a system.

Systems and System Models:

- 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.

Energy and Matter:

- 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.
- Energy drives the cycling of matter within and between systems.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Using Science – U1

- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.

Big Ideas Sequence 1

Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere or longer-term changes due to: variations in solar output, Earth's orbit, the orientation of its axis, or even more gradual atmospheric changes due to plants and other organisms. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions about:

1. patterns in data that connect natural processes and changes in global temperatures over the past century.

Develop and use models to understand:

1. Earth's energy budget and the impact of energy entering and cycling throughout Earth's climate system.

Analyze and interpret data on:

1. Earth's historical climate patterns and the various factors, both outside and inside the planet that can affect the energy and temperature of the planet.
2. increasing Greenhouse gas amounts in the atmosphere and the impact of those gases on energy cycling on Earth.

3. negative feedback loops that can change or stabilize the climate on Earth, selecting one or a few:
    a. increased cloudiness reflects more incoming solar radiation, higher rainfall from more moisture in the atmosphere, net primary productivity increase, blackbody radiation, chemical weathering as a carbon dioxide sink, the ocean's solubility pump, lapse rate and altitude temperature.
4. positive feedback loops that can change or stabilize the climate on Earth, selecting one or a few:
    a. permafrost melt sparks methane release, the removal of ice high albedo, ocean circulation patterns disruption, sea level rise, rainforest drought and loss, wetland methane release, more kindle for forest fires, gas hydrates in shallow water.

Instructional Sequence 2
Unit 7: Earth Systems: Changing Earth

Az Science Standard Plus HS+E.E1U3.11

Develop and use a quantitative model to illustrate the relationship among Earth systems and the degree to which those relationships are being modified due to human activity.

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Climate change can occur when certain parts of Earth's systems are altered.
- Though the magnitudes of humans' impacts are greater than they have ever been, so too are humans' abilities to model, predict, and manage current and future.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.
- As the global human population increases and people's demands for better living conditions increase, resources considered readily available in the past, such as land for agriculture or drinkable water, are becoming scarcer and more valued.

Science and Engineering Practices

Developing and Using Models:

- Design a test of a model to ascertain its reliability.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Engaging in Argument from Evidence:

- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Construct a counter-argument that is based on data and evidence that challenges another proposed argument.
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Crosscutting Concepts

Cause and Effect:

- Changes in systems may have various causes that may not have equal effects.
- 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.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Systems and System Models:

- 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.

Scale, Proportion, and Quantity:

- 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).
- Patterns observable at one scale may not be observable or exist at other scales.

Using Science – U3

- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.
- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.
- When designing a new system or product engineers have to take account of ethical values, political and economic realities as well as science and technology.

Big Ideas Sequence 2

Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities, as well as to changes in human activities.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use quantitative models to explain how:

1. Earth's temperature is rising due to increase in greenhouse gases, causing change in Earth's systems (i.e., the melting of ice caps, oceans rising, species migration and extinction, severe weather and increased pollution).

Construct an argument from evidence:

1. to describe a chain of reasoning that includes how increases in the size of the human populations causes increases in the consumption of natural resources, which in turn affects Earth systems.
2. about how engineered solutions alter the effects of human populations on Earth systems by changing the rate of natural resource consumption or mitigating the effects of changes in Earth systems.

Unit 8: Earth Systems: Resources

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.
L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

Instructional Sequence 1

Az Science Standard Plus HS+E.E1U3.9

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Az Science Standard Essential HS.E1U3.14

Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other.

Az Science Standard Essential HS.L2U3.18

Obtain, evaluate, and communicate about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem.

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Historically, humans have populated regions that are climatically, hydrologically, and geologically advantageous for fresh water availability, food production via agriculture, commerce, and other aspects of civilization.
- Resource availability affects geopolitical relationships and can limit development.
- Much energy production today comes from nonrenewable sources, such as coal and oil.
- However, advances in related science and technology are reducing the cost of energy from renewable resources, such as sunlight.
- As a result, future energy supplies are likely to come from a much wider range of sources.

CI L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

- Anthropogenic changes (induced by human activity) in the environment - including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change - can disrupt an ecosystem and threaten the survival of some species.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that require relevant empirical evidence to answer.
- Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.
- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design.
- Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations

Obtaining, Evaluating, and Communicating Information:

- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects.

Engaging in Argument from Evidence:

- Construct a counter-argument that is based on data and evidence that challenges another proposed argument.
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

Crosscutting Concepts

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Feedback (negative or positive) can stabilize or destabilize a system.

Systems and System Models:

- 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.

Cause and Effect:

- Changes in systems may have various causes that may not have equal effects.
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Using Science – U3

- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.
- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.

Big Ideas Sequence 1

Resource availability has guided the development of human society. All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits. New technologies and regulations can change the balance of these factors.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain and evaluate information from a variety of valid and reliable sources, potentially including theories, simulations, peer review, or students' own investigations, to construct explanations about how:

1. changes in natural resources, natural hazards, and climate impact human systems and the human solutions (i.e., efforts to increase renewable energy consumption) to these occurrences.

Develop and use models:

1. to predict effects of human activity (i.e., overpopulation, overexploitation, adverse habitat alterations, pollution, invasive species, changes in climate) on biodiversity.
    a. use logical and realistic inputs for a simulation that shows an understanding of the reliance of ecosystem function and productivity on biodiversity.

Engage in arguments from evidence that:

1. changes in natural resources and climate change due to human activity affect the biodiversity of an ecosystem, including:
    b. Natural hazard occurrences that can affect human activity and have significantly altered the sizes and distributions of human populations in particular regions.
    c. Changes in climate affect human activity (i.e., agriculture) and human populations, driving mass migrations.
    d. Features of human societies that have been affected by the availability of natural resources.
    e. Evidence of the dependence of human populations on technological systems to acquire natural and/or renewable resources and to modify physical settings.

Instructional Sequence 2
Unit 8: Earth Systems: Resources

Az Science Standard Plus HS+E.E1U3.10

Ask questions, define problems, and evaluate a solution to a complex problem, based on prioritized criteria and tradeoffs, that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Az Science Standard Essential HS.L2U3.18

Obtain, evaluate, and communicate about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem.

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Materials important to modern technological societies are not uniformly distributed across the planet (e.g., oil in the Middle East, gold in California).
- Most elements exist in Earth's crust at concentrations too low to be extracted, but in some locations— where geological processes have concentrated them—extraction is economically viable.

CI L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

- [Overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change]. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that require relevant empirical evidence to answer.
- Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts.
- Use investigations to gather evidence to support explanations or concepts.

Constructing Explanations and Designing Solutions:

- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects.
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Crosscutting Concepts

Energy and Matter:

- 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.
- Energy drives the cycling of matter within and between systems.

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Systems and System Models:

- 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.

Using Science – U3

- All innovations consume resources of some kind including financial resources so decisions have to be made when there are competing demands. These decisions, whether at governmental, local or individual level, should be informed by understanding of the scientific concepts and the technological principles involved.
- When designing a new system or product engineers have to take account of ethical values, political and economic realities as well as science and technology.
- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.
- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.

Big Ideas Sequence 2

Economic, political, social, and cultural differences can influence the effects on the environment based on what a majority of the population values. A solution to environmental impacts and issues is not linear and requires a deep understanding of the different perspectives of all factors in creating it.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions and define problems to carry out an investigation:

1. corresponding to real world data that explores factors including costs, availability of technologies, understanding management of resources, and human sustainability and biodiversity (i.e., if an ecosystem is not able to sustain biodiversity, its ability to sustain a human population is also small).
2. that illustrates the effect on one component when other components in the system are altered (i.e., effects of technology, human populations, natural resources, biodiversity).

Design and evaluate solutions:

1. for an environmental problem based on societal needs for energy or mineral resources that considers various economic, political, and social differences, including:
    a. the cost of extracting or developing the energy reserve or mineral resource.

b. the cost and benefit of a designed solution.

c. the feasibility costs and benefits or recycling or reusing the mineral resource, if applicable.

Biology
SC49

Scope and Sequence
High School Biology

Life science focuses on the patterns, processes, and relationships of living organisms. At the high school level, students apply concepts learned in earlier grades to real-world situations and investigations using the science and engineering practices to fully explore phenomena and to develop solutions to societal problems related to food, energy, health, and environment. The field of life science is rapidly advancing and new technology and information related to the study of life processes is being developed daily. Students in high school should have access to up-to-date information in the field while simultaneously gaining understanding of the historical developments which shaped today's understandings within the field. The standards for life science encompass the areas of cells and organisms; ecosystems, interactions, energy and dynamics; heredity; and biological diversity. Like Earth and space sciences and physical sciences, "connections" with the life science standards allow educators to make connections across scientific disciplines. The essential standards are those that every high school student is expected to know and understand. Plus standards in life science are designed to extend the concepts learned in the essential standards to prepare students for entry level college courses.

Note:

- The standard number is designed for recording purposes and does not imply instructional sequence or importance.
- In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline.

Unit #	Unit	Standards
1	Matter and Energy in Organisms	**HS+B.L2U1.8** Develop and use models to develop a scientific explanation that illustrates how photosynthesis transforms light energy into stored chemical energy and how cellular respiration breaks down macromolecules for use in metabolic processes. **Plus HS+B.L1U1.4** Develop and use models to explain the interdependency and interactions between cellular organelles.
		Essential HS+B.L1U1.7 Develop and use models to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms (plant and animal). **Plus HS+B.L1U1.5** Analyze and interpret data that demonstrates ~~the relationship between cellular function and~~ the diversity of protein functions.
2	Homeostasis and Cell Function	**Essential HS.L1U1.20** Ask questions and/or make predictions based on observations and evidence to demonstrate how cellular organization, structure, and function allow organisms to maintain homeostasis.
		Plus HS+B.L1U1.6 Develop and use models to show how transport mechanisms function in cells. **Plus HS+B.L1U1.4** Develop and use models to explain the interdependency and interactions between cellular organelles.

3	Growth, Development, and Reproduction of Organisms	**Essential HS.L1U1.22** Construct an explanation for how cellular division (mitosis) is the process by which organisms grow and maintain complex, interconnected systems. **Plus HS+B.L1U1.9** Develop and use a model to communicate how a cell copies genetic information to make new cells during asexual reproduction (mitosis). **Plus HS+B.L1U1.4** Develop and use models to explain the interdependency and interactions between cellular organelles.
		Essential HS.L1U3.23 Obtain, evaluate, and communicate the ethical, social, economic and/or political implications of the detection and treatment of abnormal cell function. **Plus HS+B.L1U1.4** Develop and use models to explain the interdependency and interactions between cellular organelles.
4	Matter and Energy in Ecosystems	**Essential HS.L2U1.21** Obtain, evaluate, and communicate data showing the relationship of photosynthesis and cellular respiration; flow of energy and cycling of matter. **Essential HS.L2U1.19** Develop and use models that show how changes in the transfer of matter and energy within an ecosystem and interactions between species may affect organisms and their environment.
		Plus HS+B.L2U1.3 Use mathematics and computational thinking to support claims for the cycling of matter and flow of energy through trophic levels in an ecosystem.
		Essential HS.E1U3.14 Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other.
5	Ecosystems and Populations	**Plus HS+B.L2U1.1**Develop a model showing the relationship between limiting factors and carrying capacity, and use the model to make predictions on how environmental changes impact biodiversity.
		Plus HS+B.L4U1.2 Engage in argument from evidence that changes in environmental conditions or human interventions may change species diversity in an ecosystem.
		Essential HS.L2U3.18 Obtain, evaluate, and communicate about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem. **Essential HS.P1U3.4** Obtain, evaluate, and communicate information about how the use of chemistry related technologies have had positive and negative ethical, social, economic, and/or political implications **Essential HS.P4U3.9** Engage in argument from evidence regarding the ethical, social, economic, and/or political benefits and liabilities of energy usage and transfer.

		Essential HS.E1U3.14 Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other.
6	Natural Selection and Population Change	**Plus HS+B.L4U1.14** Construct an explanation based on scientific evidence that the process of natural selection can lead to adaptation. **Essential HS.L4U1.28** Gather, evaluate, and communicate multiple lines of empirical evidence to explain the mechanisms of biological evolution.
		Essential HS.L4U1.27 Obtain, evaluate, and communicate evidence that describes how changes in frequency of inherited traits in a population can lead to biological diversity.
		Plus HS+B.L4U1.13 Obtain, evaluate, and communicate multiple lines of empirical evidence to explain the change in genetic composition of a population over successive generations.
7	Inheritable Traits	**Essential HS.L3U1.24** Construct an explanation of how the process of sexual reproduction contributes to genetic variation.
		Plus HS+B.L3U1.10 Use mathematics and computational thinking to explain the variation that occurs through meiosis and calculate the distribution of expressed traits in a population.
		Plus HS+B.L3U1.11 Construct an explanation for how the structure of DNA and RNA determine the structure of proteins that perform essential life functions. **Plus HS+B.L1U1.5** Analyze and interpret data that demonstrates the relationship between cellular function ~~and the diversity of protein functions.~~ **Plus HS+B.L1U1.4** Develop and use models to explain the interdependency and interactions between cellular organelles.
		Essential HS.L3U1.25 Obtain, evaluate, and communicate information about the causes and implications of DNA mutation. **Plus HS+B.L3U1.12** Analyze and interpret data on how mutations can lead to increased genetic variation in a population.
		Essential HS.L3U3.26 Engage in argument from evidence regarding the ethical, social, economic, and/or political implications of a current genetic technology.

MESA PUBLIC SCHOOLS
MESA, ARIZONA

Unit 1: Energy and Matter in Organisms

L1: Organisms are organized on a cellular basis and have a finite life span.
L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

Instructional Sequence 1

Az Science Standard Plus HS+B.L2U1.8

Develop and use models to develop a scientific explanation that illustrates how photosynthesis transforms light energy into stored chemical energy and how cellular respiration breaks down macromolecules for use in metabolic processes.

Az Science Standard Plus HS+B.L1U1.4

Develop and use models to explain the interdependency and interactions between cellular organelles.

Note: Relevant organelles (chloroplast and mitochondria) should be taught to understand Photosynthesis and Cellular Respiration.

CI L2: Organisms require a supply of energy and materials for which they often depend on, and compete with, other organisms.

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- The sugar molecules thus formed contain carbon, hydrogen, and oxygen.
- For example, aerobic (in the presence of oxygen) cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles.
- Anaerobic (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy loss to the surrounding environment.

L1: Organisms are organized on a cellular basis and have a finite life span.

- Within cells there are many molecules of different kinds which interact in carrying out the functions of the cell.
- In multicellular organisms cells communicate with each other by passing substances to nearby cells to coordinate activity.
- A membrane around each cell plays an important part in regulating what can enter or leave a cell.

Science and Engineering Practices

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Constructing Explanations and Designing Solutions:

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

Crosscutting Concepts

Systems and System Models:

- 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.

Structure and Function:

- 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.
- 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.

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.

Using Science – U1

- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.

Big Ideas Sequence 1

Food provides materials and energy for organisms to carry out the basic functions of life and to grow. Green plants and some bacteria are able to use energy from the Sun to create complex food molecules (photosynthesis). Animals obtain energy by breaking down these molecules (cellular respiration) and are ultimately dependent on green plants as their source of energy.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop a model from evidence that describes:

1. the particular function of cell parts in terms of their contributions to overall cellular functions.
   a. System 1: How photosynthesis transforms light energy into stored energy (i.e., light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen).

b. System 2: How cellular respiration breaks down macromolecules for use in metabolic processes (i.e., the bonds of food molecules, with and without oxygen, are broken down to produce energy and release carbon dioxide).

Plan and carry out investigations to describe:

1. the relationship between the exchange of carbon between organisms and the environment.
2. the role of storing carbon in organisms as part of the carbon cycle. *(Note: Connects to Unit 1 Sequence 1.)*

Construct an explanation based on evidence that explains:

1. how energy inputs to cells occur either by photosynthesis or by taking in food.
2. the interdependence and interactions between the chloroplast and mitochondria inputs and outputs.

Instructional Sequence 2
Unit 1: Matter and Energy in Organisms

Az Science Standard Essential HS+B.L1U1.7

Develop and use models to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms (plant and animal).

Az Science Standard Plus HS+B.L1U1.5

Analyze and interpret data that demonstrates ~~the relationship between cellular function and~~ the diversity of protein functions.

Note: Relationship between cellular function taught in Unit 7.

CI L1: Organisms are organized on a cellular basis and have a finite life span.

- Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as water, proteins, carbohydrates, lipids, and nucleic acids.
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.
- Activity within different types of cells is regulated by enzymes.

Science and Engineering Practices

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems
- Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

Planning and Carrying Out Investigations:

- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Use investigations to gather evidence to support explanations or concepts.

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data.

Crosscutting Concepts

Structure and Function:

- 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.

Systems and System Models:

- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Feedback (negative or positive) can stabilize or destabilize a system.

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.

Big Ideas Sequence 2

Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules. This system has a hierarchical structure as related to their function.

Within cells there are many molecules of different kinds which interact in carrying out the functions of the cell. Activity with different types of cells is regulated by enzymes.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use a model:

1. to identify and describe the hierarchical organization of interacting systems (i.e., cells > tissue > organ > organ system > organism) and processes (i.e., transport of fluids, motion) of body systems in multicellular organisms.
2. that illustrates specific functions based on structure within multicellular organisms (plant and animal).

Plan and carry out an investigation:

1. to show that the functions of enzymes are vital for life and serve a wide range of important roles in the body, such as aiding in digestion and metabolism.

Analyze data to show that properties of enzymes include:

1. biological catalysts and speed up reactions although they are not changed in the reaction.

Unit 2: Homeostasis and Cell Function of Organisms

L1: Organisms are organized on a cellular basis and have a finite life span.

Instructional Sequence 1

Az Science Standard Essential HS.L1U1.20

Ask questions and/or make predictions based on observations and evidence to demonstrate how cellular organization, structure, and function allow organisms to maintain homeostasis.

Note: Unit phenomena being homeostasis.

CI L1: Organisms are organized on a cellular basis and have a finite life span.

- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range.
- Outside that range (e.g., at a too high or too low external temperature, with too little food or water available), the organism cannot survive.
- Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results.
- Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts.
- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
- Use investigations to gather evidence to support explanations or concepts.

Crosscutting Concepts

Cause and Effect:

- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Feedback (negative or positive) can stabilize or destabilize a system.

Systems and System Models:

- 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.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.

Big Ideas Sequence 1

Organisms must maintain a stable internal environment to survive. This is accomplished through feedback mechanisms.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions about:

1. how mechanisms affects homeostasis (positive and negative feedback).

Plan and carry out an investigation:

1. to collect data that explains how changes in the external environment of a living system cause changes in the internal environment (homeostasis).
2. to predict the relationship of positive or negative feedback to the change of the internal conditions of an organism.

Instructional Sequence 2
Unit 2: Homeostasis and Cell Function of Organsims

Az Science Standard Plus HS+B.L1U1.6

Develop and use models to show how transport mechanisms function in cells.

Az Science Standard Plus HS+B.L1U1.4

Develop and use models to explain the interdependency and interactions between cellular organelles.

Note: Relevant organelles (cell membrane) should be taught to understand cellular transport.

CI L1: Organisms are organized on a cellular basis and have a finite life span.

- Within cells there are many molecules of different kinds which interact in carrying out the functions of the cell.
- In multicellular organisms, cells communicate with each other by passing substances to nearby cells to coordinate activity.
- A membrane around each cell plays an important part in regulating what can enter or leave a cell.
- Hormones, released by specialized tissues, regulate activity in other organs and tissues and affect the overall function of the organism.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Use investigations to gather evidence to support explanations or concepts.

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.
- Design a test of a model to ascertain its reliability.
- Develop a complex model that allows for manipulation and testing of a proposed process or system.

Constructing Explanations and Designing Solutions:

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

Crosscutting Concepts

Structure and Function:

- 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.

Systems and System Models:

- 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.
- 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.
- 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.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.

Big Ideas Sequence 2

A membrane around each cell plays an important part in regulating what can enter or leave a cell.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain and communicate information that:

1. in multicellular organisms, many types of chemical signals are used in homeostasis.
2. cells have proteins in their cell walls called receptors that bind to signaling molecules and initiate a physiological response. Different receptors are specific for different molecules.
3. the cell membrane is semi-permeable, keeping a balance of salts, nutrients, and proteins within a range that keeps the cell and the organism alive.

Develop and use models:

1. to identify and describe the structure of the cell membrane or cell wall and its relationship to the function of the organelles and the whole cell.
2. to describe the function of the cell membrane in controlling what enters and leaves the cell.

Plan and carry out an investigation to collect and analyze data:

1. that the permeability of a membrane is dependent on the organization and characteristics of the membrane lipids and proteins.
2. that some molecules (i.e., steroid hormones) can pass by passive transport (i.e., diffusion, osmosis, facilitated diffusion) while other molecules (i.e., digestive hormones) require active transport (i.e., exocytosis, endocytosis).

Construct an explanation:

1. on how systems/mechanisms within an organism transport and regulate substances (active and passive) across the cell membrane to maintain homeostasis.

Unit 3: Growth, Development, and Reproduction of Organisms

L1: Organisms are organized on a cellular basis and have a finite life span.

Instructional Sequence 1

Az Science Standard Essential HS.L1U1.22

Construct an explanation for how cellular division (mitosis) is the process by which organisms grow and maintain complex, interconnected systems.

Az Science Standard Plus HS+B.L1U1.9

Develop and use a model to communicate how a cell copies genetic information to make new cells during asexual reproduction (mitosis).

Note: This standard should cover the S-Phase of the Cell Cycle and how DNA replication is a semi-conservative process. Students do not need to memorize the stages of mitosis, only to understand them as the cycle of organism growth, repair, and asexual reproduction.

Az Science Standard Plus HS+B.L1U1.4

Develop and use models to explain the interdependency and interactions between cellular organelles.

Note: Relevant organelles (nucleus) should be taught to understand Mitosis.

CI L1: Organisms are organized on a cellular basis and have a finite life span.

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow.
- Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.
- Most cells are programmed for a limited number of cell divisions.
- Organisms die if their cells are incapable of further division.

Science and Engineering Practices

Planning and Carrying Out Investigations:

- Use investigations to gather evidence to support explanations or concepts.

Constructing Explanations and Designing Solutions:

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Evaluate the merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

Crosscutting Concepts

Patterns:

- Empirical evidence is needed to identify patterns.

Systems and System Models:

- 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.
- 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.

Structure and Function:

- 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.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

Organisms grow and maintain systems by undergoing cell division. This process has a logical sequence of events that can be supported with evidence. When cells divide, the information needed to make more cells is encoded in the arrangement of molecules within DNA. The structure of DNA allows for fast and accurate replication.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Carry out an investigation to:

1. explore the role of mitosis and differentiation in producing and maintaining complex organisms. *Note: Memorization of the stages of mitosis is not required.*

Develop and use models:

1. to explain how cells go through the process of replication in the S-phase of the cell cycle and construct an explanation that includes:
    a. All cells contain DNA.
    b. DNA contains regions that are called genes.
    c. The sequence of genes contains instructions that code for proteins.
    d. Groups of specialized cells (tissues) use proteins to carry out functions that are essential to the organism.

Construct an explanation:

1. to illustrate that the pattern of mitotic cell division results in more cells that allow growth of the organism, can then differentiate to create different cell types, and can replace dead cells to maintain a complex organisms and organism systems.
2. about the S-phase that supports the relationship between the DNA structure, the semi-conservative and accurate process of replication.

Instructional Sequence 2
Unit 3: Growth, Development, and Reproduction of Organisms

Az Science Standard Essential HS.L1U3.23

Obtain, evaluate, and communicate the ethical, social, economic and/or political implications of the detection and treatment of abnormal cell function.

Az Science Standard Plus HS+B.L1U1.4

Develop and use models to explain the interdependency and interactions between cellular organelles.

Note: Relevant organelles (lysosomes) should be taught to understand how cells deal with abnormal cell function.

CI L1: Organisms are organized on a cellular basis and have a finite life span.

- Given a suitable medium, cells from a variety of organisms can be grown in situ, that is, outside the organism. These cell cultures are used by scientists to investigate cell functions and have medical implications such as the production of vaccines, screening of drugs, and in vitro fertilization.
- Diseases, which may be caused by invading microorganisms, environmental conditions or defective cell programming, generally result in disturbed cell function.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design.
- Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Crosscutting Concepts

Cause and Effect:

- Changes in systems may have various causes that may not have equal effects.

Structure and Function:

- 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.
- 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.

Using Science – U3

- When designing a new system or product engineers have to take account of ethical values, political and economic realities as well as science and technology.
- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.

Big Ideas Sequence 2

Our understanding of the cell cycle and genetics allows humans to manipulate/influence abnormal cell function. Decisions about whether certain actions should be taken will require ethical and moral judgments which are not provided by knowledge of science.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions about:

1. symptoms and mechanism of the abnormal cell function that cause disease.
2. medical implications of gene therapies, DNA profiling, the screening of drugs, and in vitro fertilization.

Obtain, evaluate, and communicate information by:

1. critically reading and summarizing multiple sources concerning the causes and effects of a cellular disease (abnormal cell function) including the
    a. current prevention and/or treatment of abnormal cell function and the ethical, social, economic and/or political implications and challenges of the treatment.

Develop a model:

1. to describe cellular processes that relate to abnormal cell function and division including the interactions between cellular organelles that contribute to this process.

Unit 4: Matter and Energy in Ecosystems

L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.
E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Instructional Sequence 1

Az Science Standard Essential HS.L2U1.21

Obtain, evaluate, and communicate data showing the relationship of photosynthesis and cellular respiration; flow of energy and cycling of matter.

Az Science Standard Essential HS.L2U1.19

Develop and use models that show how changes in the transfer of matter and energy within an ecosystem and interactions between species may affect organisms and their environment.

Note: This sequence does not include the process of photosynthesis or cellular respiration at the cellular level and processes. The focus will be that atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.

CI L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
- Plants or algae form the lowest level of the food web.
- The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways.
- At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. Competition among species is ultimately competition for the matter and energy needed for life.

Science and Engineering Practices

Obtaining, Evaluating and Communicating Information:

- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

Constructing Explanations and Designing Solutions:

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.

Systems and System Models:

- 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.
- 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.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

The persistence of an ecosystem depends on the availability of energy, resources, and materials in an environment. Energy and matter is cycled through the biogeochemical cycles (i.e., carbon cycle).

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate and communicate information:

1. about how the extreme fluctuations in conditions or the size of any population can challenge the functioning of ecosystems in terms of resources and habitat availability, and can even result in a new ecosystem.
2. to understand that energy from photosynthesis and respiration drives the cycling of matter and flow of energy under aerobic or anaerobic conditions within an ecosystem.

Develop and use models that demonstrate:

1. the transfer and conservation of matter and energy within an ecosystem (i.e., trophic levels) and interactions between species (i.e., competition, symbiotic relationships, predator-prey relationships).
2. that all organisms take in matter and rearrange the elements in chemical reactions.
3. that photosynthesis captures energy in sunlight to create chemical products that can be used as food in cellular respiration.

4. that cellular respiration is the process by which the matter in food (sugars, fats) reacts chemically with other compounds, rearranging the matter to release energy used by the cell for essential life processes.

Constructing explanations for:

1. how matter and energy transfer through the interactions of biotic and abiotic factors in the system in which they live, including but not limited to photosynthesis and cellular respiration.

Instructional Sequence 2
Unit 4: Matter and Energy in Ecosystems

Az Science Standard Plus HS+B.L2U1.3

Use mathematics and computational thinking to support claims for the cycling of matter and flow of energy through trophic levels in an ecosystem.

CI L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

- Matter and energy are conserved in each change. This is true of all biological systems, from individual cells to ecosystems.
- Energy is transferred from one system of interacting molecules to another.
- Plants or algae form the lowest level of the food web.
- At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web, and there is a limit to the number of organisms that an ecosystem can sustain.

Science and Engineering Practices

Using Mathematics and Computational Thinking:

- Create a simple computational model or simulation of a designed device, process, or system.
- Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.

Developing and Using Models:

- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Crosscutting Concepts

Energy and Matter:

- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.

Patterns:

- Mathematical representations are needed to identify some patterns.

Systems and System Models:

- 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.
- 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.

Scale, Proportion, and Quantity:

- The significance of a phenomena is dependent on the scale, proportion, and quantity at which it occurs.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- 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).

Using Science – U1

- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.

Big Ideas Sequence 2

Energy is not created or destroyed, but only 10% of energy can be transferred directly from one organism to another. Matter used for carrying out life processes is also not created or destroyed. It must be consumed or re-assembled from existing materials.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use mathematics and computational thinking to create a simple computational model:

1. to describe the transfer of matter (as elements and molecules) and flow of energy upward between organisms and their environment.
2. to identify the relative proportion of organisms, based on biomass and energy, at each trophic level by correctly identifying producers and consumers.
3. that supports claims for the pattern of conservation with the transfer of energy and matter through a system.

Instructional Sequence 3
Unit 4: Energy and Matter in Ecosystems

Az Science Standard Essential HS.E1U3.14

Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other.

Note: In this standard, human activities are discussed at the surface level. Details about technology and resources use will be taught in-depth in a later unit. Natural resources can include but not limited to: access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can include but are not limited to interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts) Examples of the results of changes in climate can include but not limited to factors that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

CI E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.
- As the global human population increases and people's demands for better living conditions increase, resources considered readily available in the past, such as land for agriculture or drinkable water, are becoming scarcer and more valued.
- All forms of resource extraction and land use have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits.
- Natural hazards and other geologic events have shaped the course of human history.
- Natural hazards can be local, regional, or global in origin, and their risks increase as populations grow.
- Human activities can contribute to the frequency and intensity of some natural hazards.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.
- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Engaging in Argument from Evidence:

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

Crosscutting Concepts

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Patterns:

- 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.

Cause and Effect:

- 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.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Using Science – U3

- All innovations consume resources of some kind including financial resources so decisions have to be made when there are competing demands. These decisions, whether at governmental, local or individual level, should be informed by understanding of the scientific concepts and the technological principles involved.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.

Big Ideas Sequence 3

Natural hazards, human activities, and changes in climate control the growth of certain plants and animals and change the resources available in an ecosystem. Natural resources can include but not limited to access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can include but are not limited to interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts) Examples of the results of changes in climate can include but not limited to factors that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate, and communicate information:

1. about human extraction of natural resources and their associated economic, social, environmental, and geopolitical costs and risks, as well as benefits.
2. about specific cause and effect relationships between environmental factors (natural hazards, changes in climate, and the availability of natural resources) of human activities.
3. about natural hazard occurrences that can affect human activity having significantly altered the sizes and distributions of human populations in particular regions.
4. about changes in climate that affect human activity (e.g., agriculture) and human populations that can drive mass migrations (past and/or current).

Engage in argument from evidence:

1. about how human activities affect the stability of available resources and the pattern of climate change.

Unit 5: Ecosystems and Populations

L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.
L4: The unity and diversity of organisms, living and extinct, is the result of evolution.
P1: All matter in the Universe is made of very small particles.
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.
E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Instructional Sequence 1

Az Science Standard Plus HS+B.L2U1.1

Develop a model showing the relationship between limiting factors and carrying capacity and use the model to make predictions on how environmental changes impact biodiversity.

CI L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support.
- These limits result from such factors as the availability of living and non-living resources and from such challenges as predation, competition, and disease.
- Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite.
- This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results.
- Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena and move flexibly between model types based on merits and limitations.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.
- Create a simple computational model or simulation of a designed device, process, or system.

Crosscutting Concepts

Scale, Proportion, and Quantity:

- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- 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).

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Changes in systems may have various causes that may not have equal effects.

Stability and Change:

- Much of science deals with construction explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Using Science – U1

- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. Different factors affect carrying capacities at different scales.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions about:

1. environmental factors that cause populations to increase or decrease within the ecosystem (i.e., availability of food, water, and shelter; predation; natural hazards; disease).

Develop a model:

1. that shows the relationship between limiting factors and carrying capacity at different scales (i.e., some factors have larger effects than do other factors, factors are interrelated, the significance of a factor is dependent on the scale (i.e., a pond vs. an ocean)).

Use mathematics and computational thinking:

1. to make predictions from graphs, charts, simulations, or historical data sets on how environmental changes impact biodiversity (i.e., linear growth vs. exponential growth, logistic growth).

Instructional Sequence 2
Unit 5: Ecosystems and Populations

Az Science Standard Plus HS+B.L4U1.2

Engage in argument from evidence that changes in environmental conditions or human interventions may change species diversity in an ecosystem.

CI L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions.
- If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem.
- Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- Moreover, anthropogenic changes (induced by human activity) in the environment —including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change — can disrupt an ecosystem and threaten the survival of some species.

CI L4: The diversity of organisms, living and extinct, is the result of evolution.

- Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Engaging in Argument from Evidence:

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Construct a counterargument that is based on data and evidence that challenges another proposed argument.

Crosscutting Concepts

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.

Cause and Effect:

- Changes in systems may have various causes that may not have equal effects.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.

- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

Big Ideas Sequence 2

The carrying capacities can be disrupted temporarily or permanently by a biological or physical disturbance to an ecosystem.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate, and communicate (mathematical) information:

1. to identify the most important factors that determine biodiversity of an ecosystem and changes over time in numbers and types of organisms in ecosystems of different capacities.
2. to identify interdependence of factors (living and non-living) in biodiversity and population size and resulting effect on carrying capacity.
3. about the effects of human intervention activity (i.e., conservation) on a threatened or endangered species or to the genetic variation within a species, with the ultimate goal on biodiversity being avoiding extinction.

Engage in argument from evidence:

1. about current real-world examples of species whose carrying capacities have been disrupted (stability and change) by biological/physical disturbances and how they respond.
2. that critiques proposed human interventions and make arguments/counterarguments to the effectiveness.

Instructional Sequence 3
Unit 5: Ecosystems and Populations

Az Science Standard Essential HS.L2U3.18

Obtain, evaluate, and communicate about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem.

Az Science Standard Essential HS.P1U3.4

Obtain, evaluate, and communicate information about how the use of chemistry related technologies have had positive and negative ethical, social, economic, and/or political implications

Az Science Standard Essential HS.P4U3.9

Engage in argument from evidence regarding the ethical, social, economic, and/or political benefits and liabilities of energy usage and transfer.

Az Science Standard Essential HS.E1U3.14

Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other.

Note: Human impact should be taught through the lens of the effect on BIODIVERSITY of ecosystems regardless of the source. Below are suggestions, you are not limited to these ideas:

- *Biology concepts: habitat fragmentation, urbanization, species conservation efforts, more are listed below.*
- *Chemistry concepts: fertilizer use and runoff leading to algae blooms (Haber process), product production and/or waste, increased CO_2 leading to ocean acidification.*
- *Physics concepts: renewable and nonrenewable energy sources (fossil fuels, solar, nuclear).*

CI L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

- Anthropogenic changes (induced by human activity) in the environment —including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change —an disrupt an ecosystem and threaten the survival of some species.

CI L4: The diversity of organisms, living and extinct, is the result of evolution.

- Humans depend on the living world for the resources and other benefits provided by biodiversity.
- But human activity is having positive and negative impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change.
- These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things.
- Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.

CI P1: All matter in the Universe is made of very small particles.

- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.
- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.

CI P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- Across the world, the demand for energy increases as human populations grow and because modern lifestyles require more energy, particularly in the convenient form of electrical energy.
- Therefore other ways of generating electricity have to be sought, whilst reducing demand and improving the efficiency of the processes in which we use it.

CI E1: The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate.

- New technologies and regulations can change the balance of these factors.
- Much energy production today comes from nonrenewable sources, such as coal and oil.
- However, advances in related science and technology are reducing the cost of energy from renewable resources, such as sunlight.
- As a result, future energy supplies are likely to come from a much wider range of sources.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Engaging in Argument from Evidence:

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Construct a counter-argument that is based on data and evidence that challenges another proposed argument.
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

Crosscutting Concepts

Cause and Effect:

- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.

Energy and Matter:

- Energy drives the cycling of matter within and between systems.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Using Science – U3

- When designing a new system or product engineers have to take account of ethical values, political and economic realities as well as science and technology.
- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.

Big Ideas Sequence 3

Human activity has positive and negative ethical, social, economic, and political implications on the biodiversity of an ecosystem.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate and communicate information:

1. about the benefits, as well as the ethical, social, economic, and political implications, of maintaining a healthy and balanced ecosystem.
2. based on evidence about human factors, both positive and negative, that affect biodiversity and populations.

Engage in argument:

1. by communicating data from investigations about how human activities both positively and negatively (overpopulation, overexploitation, climate change, energy use, invasive species, pollution) affect biodiversity, including speciation and extinction.
2. from multiple resources that humans use increasing amounts of both renewable and nonrenewable sources (fossil fuels, solar, nuclear), that usage can influence the biodiversity of an ecosystem, and how modern technology can make sustainable energy sources more viable.
3. which includes the positive and negative ethical, social, economic, and political implications of new technologies, different kinds of energy use, and human activities on biodiversity.

Unit 6: Natural Selection and Population Change

L4: The unity and diversity of organisms, living and extinct, is the result of evolution.

Instructional Sequence 1

Az Science Standard Plus HS+B.L4U1.14

Construct an explanation based on scientific evidence that the process of natural selection can lead to adaptation.

Note: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.

Az Science Standard Essential HS.L4U1.28

Gather, evaluate, and communicate multiple lines of empirical evidence to explain the mechanisms of biological evolution.

CI L4: The unity and diversity of organisms, living and extinct, is the result of evolution.

- Natural selection leads to adaptation —that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment.
- That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Adaptation also means that the distribution of traits in a population can change when conditions change.
- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals.
- The traits that positively affect survival are more likely to be reproduced and thus are more common in the population.
- Natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Constructing Explanations and Designing Solutions:

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Crosscutting Concepts

Patterns:

- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Cause and Effect:

- 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.
- Changes in systems may have various causes that may not have equal effects.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.

Big Ideas Sequence 1

Living things are found in certain environments because they have traits that enable them to survive specifically within those environments. Adaptations come about because of traits that help the organism survive, reproduce, and get passed on during reproduction. Biological evolution occurs through the process of natural selection, and there are multiple sources of evidence in support of this process.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain and evaluate information that addresses how:

1. as a species grows in number, competition for limited resources can arise causing individuals in a species to develop genetic variation (through mutations and sexual reproduction) in response that is passed on to their offspring.
2. individuals with traits that give competitive advantages can survive and reproduce at higher rates than individuals without the traits because of the competition for limited resources.
3. individuals that survive and reproduce at a higher rate will provide their specific genetic variations to a greater proportion of individuals in the next generation, and over many generations, groups of individuals can evolve into a different species.

Construct an explanation based on evidence and by applying scientific reasoning:

1. that Identifies patterns about the cause and effect relationship between natural selection and adaptation including:
   a. changes in a population when some feature of the environment changes.
   b. the fact that individuals in a species have genetic variation (through mutations and sexual reproduction) that is passed on to their offspring.

c. individuals can have specific traits that give them a competitive advantage relative to other individuals in the species.

2. to the patterns and changes of natural selection (survival of the fittest, evolution, reproduction) through advantageous heritable traits.
3. about the difference between natural selection and biological evolution (i.e., natural selection is a process, and biological evolution can result from that process).
4. that explains the cause and effect relationship between genetic variation, the selection of traits that provide comparative advantages, and the evolution of populations that all express the trait.

Instructional Sequence 2
Unit 6: Natural Selection and Population Change

Az Science Standard Essential HS.L4U1.27

Obtain, evaluate, and communicate evidence that describes how changes in frequency of inherited traits in a population can lead to biological diversity.

CI L4: The unity and diversity of organisms, living and extinct, is the result of evolution.

- The differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.
- Adaptation also means that the distribution of traits in a population can change when conditions change.
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. Species become extinct because they can no longer survive and reproduce in their altered environment.
- If members cannot adjust to change that is too fast or too drastic, the opportunity for the species' evolution is lost.

Science and Engineering Practices

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Crosscutting Concepts

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- Phenomena that occurred in the past, such as rock changes or species evolution, can also be submitted to the process of hypothesis testing.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 2

Distribution of traits in a population can change when conditions change. Over time, these changes can accumulate to the point where the survivors can no longer reproduce with some members of the population and have become a different species, or they can decline to the point of extinction of a species.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use mathematical analysis to show and simulate:

1. with data (e.g., using tables, graphs and charts) the distribution of genetic traits over time.
2. how changes to the distribution of traits in a population (stabilizing, disruptive, directional) by the physical environment (natural or human) can lead to speciation (divergent evolution) or extinction if the organisms cannot adjust quickly enough.

Obtain, evaluate, and communicate information about:

1. positive or negative effects on survival and reproduction of individuals as relating to their expression of a variable trait in a population.
2. natural selection as the cause of increases and decreases in heritable traits over time in a population, but only if it affects reproductive success.

Instructional Sequence 3
Unit 6: Natural Selection and Population Change

Az Science Standard Plus HS+B.L4U1.13

Obtain, evaluate, and communicate multiple lines of empirical evidence to explain the change in genetic composition of a population over successive generations.

CI L4: The unity and diversity of organisms, living and extinct, is the result of evolution.

- Genetic information, like the fossil record, also provides evidence of evolution.
- DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descents can be inferred by comparing the DNA sequences of different organisms.
- Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

Science and Engineering Practices

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Use investigations to gather evidence to support explanations or concepts.

Obtaining, Evaluating, and Communicating Information:

- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.
- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.

Crosscutting Concepts

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Systems and System Models:

- 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.

Patterns:

- 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.

- 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.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Using Science – U1

- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 3

Organisms in a population with advantageous heritable traits survive and reproduce better, leading to an increase in the proportion of individuals in future generations that have the trait, and to a decrease in the proportion of individuals that do not.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Plan and carry out investigations that model:

1. the change of trait frequency in gene pools over multiple generations, including:
    a. information derived from DNA sequences, which vary among species but have many similarities between species.
    b. similarities and differences of patterns of amino acid sequences among species.
    c. patterns in the fossil record (e.g., presence, location, and inferences possible in lines of evolutionary descent for multiple specimens).
    d. the pattern of anatomical and embryological similarities.

Obtain, evaluate, and communicate:

1. scientific information and empirical evidence that connects each line of evidence and the claim of common ancestry and biological evolution using at least two different formats (e.g., oral, graphical, textual and mathematical). Students cite the origin of the information as appropriate.

Unit 7: Inheritable Traits

L1: Organisms are organized on a cellular basis and have a finite life span.
L3: Genetic information is passed down from one generation of organisms to another.

Instructional Sequence 1

Az Science Standard Essential HS.L3U1.24

Construct an explanation of how the process of sexual reproduction contributes to genetic variation.

CI L3: Genetic information is passed down from one generation of organisms to another.

- In sexual reproduction, a specialized type of cell division called meiosis occurs and results in the production of sex cells, such as gametes (sperm and eggs) or spores, which contain only one member from each chromosome pair in the parent cell.
- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation.

Science and Engineering Practices

Constructing Explanations and Designing Solutions:

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.

Crosscutting Concepts

Patterns:

- Empirical evidence is needed to identify patterns.
- 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

Cause and Effect:

- 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.

Using Science – U1

- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.

Big Ideas Sequence 1
Sperm and egg cells are specialized cells, each of which has one of the two versions of each gene carried by the parent, selected at random. This sorting of genetic material, along with mutations in the DNA and the recombining of the DNA at fusion, results in genetic variation.
Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning. Obtain and evaluate information (scientific knowledge, literature, student-generated data, simulations and/or other sources for evidence) to: 1. identify and describe the inputs and outputs of meiosis. 2. make a claim that inheritable genetic variations may result from new genetic combinations through meiosis and mutations caused by environmental factors. Develop and revise models that show: 1. the patterns of genetic variation through sexual reproduction (meiosis), errors in DNA replication, and environmental factors, including gametes, crossing over, and gene recombination.

Instructional Sequence 2
Unit 7: Inheritable Traits

Az Science Standard Plus HS+B.L3U1.10

Use mathematics and computational thinking to explain the variation that occurs through meiosis and calculate the distribution of expressed traits in a population.

CI L3: Genetic information is passed down from one generation of organisms to another.

- Environmental factors can also cause mutations in genes, and viable mutations are inherited.
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population.
- Thus the variation and distribution of traits observed depend on both genetic and environmental factors.

Science and Engineering Practices

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.

Crosscutting Concepts

Patterns:

- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Using Science – U1

- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.

Big Ideas Sequence 2

Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Therefore, the variation and distribution of traits observed depend on both genetic and environmental factors.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use mathematical representations:

1. and patterns to predict the probability of expressed traits by given data by the frequency, distribution, and variation of expressed traits in the population.

Obtain, evaluate, and communicate:

1. reasons why predictions (Punnett squares) may not correspond with occurrences in a population (environmental mutations or environmental causes for on/off genes).

Instructional Sequence 3
Unit 7: Inheritable Traits

Az Science Standard Plus HS+B.L3U1.11

Construct an explanation for how the structure of DNA and RNA determine the structure of proteins that perform essential life functions.

Note: Central Dogma needs to be established DNA >RNA>Protein>Trait.

Az Science Standard Plus HS+B.L1U1.5

Analyze and interpret data that demonstrates the relationship between cellular function ~~and the diversity of protein functions.~~

Note: Diversity of protein function taught in Unit 2.

Az Science Standard Plus HS+B.L1U1.4

Develop and use models to explain the interdependency and interactions between cellular organelles.

Note: Relevant organelles (Golgi apparatus, endoplasmic reticulum, cytoskeleton) should be taught to understand cellular transport.

CI L3: Genetic information is passed down from one generation of organisms to another.

- The information passed from parents to offspring is coded in DNA molecules that form the chromosomes.
- Genes are regions in the DNA that contain the instructions that code for the formation of proteins.

CI L1: Organisms are organized on a cellular basis and have a finite life span.

- Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as water, proteins, carbohydrates, lipids, and nucleic acids.
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.

Science and Engineering Practices

Developing and Using Models:

- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.
- Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

Analyzing and Interpreting Data:

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Constructing Explanations and Designing Solutions:

- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

Structure and Function:

- 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

Cause and Effect:

- 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.

Using Science – U1

- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.

Big Ideas Sequence 3

A gene is a length of DNA, and hundreds or thousands of genes are carried on a single chromosome. Each distinct gene chiefly controls the production of a specific protein by specific organelles, which in turn affects the traits of the individual.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use a model:

1. to illustrate the process of protein synthesis and structure including the nucleus, ribosomes, endoplasmic reticulum, and Golgi apparatus.
2. to predict traits of individual organisms.

Analyze and interpret data:

1. that explains how cells contain genetic information in the form of DNA molecules and includes
   a. genes are regions in the DNA that contain the instructions that code for the formation of proteins.
   b. several organelles (i.e., nucleus, ribosome) along with DNA work together in the formation of proteins.

Construct an explanation in the form of a claim that:

1. protein synthesis and transport utilizes various organelles: Golgi apparatus, endoplasmic reticulum, ribosomes and the cytoskeleton.
2. explains the cause and effect relationships between DNA, the proteins it codes for, and the resulting traits observed in an organism. (DNA>RNA>Proteins>Trait)

Instructional Sequence 4
Unit 7: Inheritable Traits

Az Science Standard Essential HS.L3U1.25

Obtain, evaluate, and communicate information about the causes and implications of DNA mutation.

Az Science Standard Plus HS+B.L3U1.12

Analyze and interpret data on how mutations can lead to increased genetic variation in a population.

CI L3: Genetic information is passed down from one generation of organisms to another.

- Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation.
- Environmental factors can also cause mutations in genes, and viable mutations are inherited.
- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that require relevant empirical evidence to answer.
- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design.

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Constructing Explanations and Designing Solutions:

- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

Crosscutting Concepts

Cause and Effect:

- Changes in systems may have various causes that may not have equal effects.

Using Science – U1

- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.

Big Ideas Sequence 4

Changes (mutations) to genes can result in changes to DNA and traits, which can affect the structures and functions of the organism. These changes can accumulate to the point of affecting the variety of the population.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions to:

1. make connections that genetic mutations produce genetic variations that can be inherited.

Obtain, evaluate, and communicate information about:

1. the various sources of genetic variation: meiosis (crossing-over), DNA replication (mutations) and environmental factors.

Construct explanations:

1. how genetic mutations can occur due to errors during replication; and/or environmental factors.
2. the causes and implications of mutation in which they may not have equal effects.

Instructional Sequence 5
Unit 7: Inheritable Traits

Az Science Standard Essential HS.L3U3.26

Engage in argument from evidence regarding the ethical, social, economic, and/or political implications of a current genetic technology.

CI L3: Genetic information is passed down from one generation of organisms to another.

- The overall sequence of genes of an organism is known as its genome.
- More is being learned all the time about genetic information by mapping the genomes of different kinds of organisms.
- When sequences of genes are known genetic material can be artificially changed to give organisms certain features.
- In gene therapy special techniques are used to deliver into human cells genes that are beginning to help in curing disease.

Science and Engineering Practices

Engaging in Argument from Evidence:

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Construct a counter-argument that is based on data and evidence that challenges another proposed argument.
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Crosscutting Concepts

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.

Cause and Effect:

- Changes in systems may have various causes that may not have equal effects.

Using Science – U3

- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.

Big Ideas Sequence 5

When sequences of genes are known, genetic material can be artificially changed to give organisms certain features. In gene therapy, special techniques are used to deliver into human cells genes that are beginning to help in curing disease. Decisions about whether certain actions should be taken will require ethical and moral judgments which are not provided by knowledge of science.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Engage in arguments and counterarguments based on evidence:

1. regarding the ethical, social, economic, and/or political implications of a current genetic technology to include genomes, gene therapy, gene mapping and curing diseases.

Chemistry
SC71

Scope and Sequence

High School Chemistry

Physical science encompasses physical and chemical sub-processes that occur within systems. At the high school level, students gain an understanding of these processes at both the micro and macro levels through the intensive study of matter, energy, and forces. Students are expected to apply these concepts to real-world phenomena to gain a deeper understanding of causes, effects, and solutions for physical processes in the real world. The essential standards are those that every high school student is expected to know and understand. Plus standards in chemistry and physics are designed to extend the concepts learned in the essential standards to prepare students for entry level college courses. It is suggested to use the metric system within measurement.

Note:

- The standard number is designed for recording purposes and does not imply instructional sequence or importance.
- In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline.

Unit #	Unit	Standards
1	Matter	**Plus HS+C.P1U1.1** Develop and use models to demonstrate how changes in the number of subatomic particles (protons, neutrons, electrons) affect the identity, stability, and properties of the element.
		Essential HS.P1U1.1 Develop and use models to explain the relationship of the structure of atoms to patterns and properties observed within the Periodic Table and describe how these models are revised with new evidence.
		Plus HS+C.P1U1.2 Obtain, evaluate, and communicate the qualitative evidence supporting claims about how atoms absorb and emit energy in the form of electromagnetic radiation.
2	Interactions in Matter	**Essential HS.P4U1.8** Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings. **Plus HS+Phy.P4U1.6** Analyze and interpret data to quantitatively describe changes in energy within a system and/or energy flows in and out of a system.
		Plus HS+C.P1U1.3 Analyze and interpret data to develop and support an explanation for the relationships between kinetic molecular theory and gas laws.
		Plus HS+C.P1U1.4 Develop and use models to predict and explain forces within and between molecules. **Essential HS.P1U1.2** Develop and use models for the transfer or sharing of electrons to predict the formation of ions, molecules, and compounds in both natural and synthetic processes.

		Plus HS+C.P1U1.5 Plan and carry out investigations to test predictions of the outcomes of various reactions, based on patterns of physical and chemical properties
3	Changes in Matter	**HS+C.P1U1.7** Use mathematics and computational thinking to determine stoichiometric relationships between reactants and products in chemical reactions. **Plus HS+C.P1U1.5** Plan and carry out investigations to test predictions of the outcomes of various reactions, based on patterns of physical and chemical properties.
		HS+C.P1U1.6 Construct an explanation, design a solution, or refine the design of a chemical system in equilibrium to maximize production.
4	Nuclear Energy	**Essential HS.P1U3.4** Obtain, evaluate, and communicate information about how the use of chemistry related technologies have had positive and negative ethical, social, economic, and/or political implications.
		Plus HS+C.P1U3.8 Engage in argument from evidence regarding the ethical, social, economic, and/or political benefits and liabilities of fission, fusion, and radioactive decay.

MESA PUBLIC SCHOOLS
MESA, ARIZONA

Unit 1: Matter

P1: All matter in the Universe is made of very small particles.

Instructional Sequence 1

Az Science Standard Plus HS+C.P1U1.1

Develop and use models to demonstrate how changes in the number of subatomic particles (protons, neutrons, electrons) affect the identity, stability, and properties of the element.

Az Science Standard Essential HS.P1U1.1

Develop and use models to explain the relationship of the structure of atoms to patterns and properties observed within the Periodic Table and describe how these models are revised with new evidence.

Note: Sequence 1 focuses on atoms and elements. Sequence 2 focuses on the Periodic Table and interactions.

CI P1: All matter in the Universe is made of very small particles.

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns.
- The repeating patterns of the periodic table reflect patterns of outer electron states.
- The structure and interactions of matter at the bulk scale are determined by forces within and between atoms.

Science and Engineering Practices

Developing and Using Models:

- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.

Using Mathematics and Computational Thinking:

- Create a simple computational model or simulation of a designed device, process, or system.

Crosscutting Concepts

Patterns:

- Mathematical representations are needed to identify some patterns
- Empirical evidence is needed to identify patterns

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Patterns observable at one scale may not be observable or exist at other scales.
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another.

Structure and Function:

- 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.
- 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.

Using Science – U1

- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.

Big Ideas Sequence 1

An atom is the smallest unit of matter. All atoms are made up of a combination of three subatomic particles. Changing the quantities of each of these subatomic particles will have drastically different effects. These changes are evident by using the patterns conveniently present within the periodic table. These patterns allow us to discover any element's identity, stability and other various properties.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use models to identify:

1. and predict interactions between a positively-charged nucleus composed of both protons and neutrons and the surrounding negatively-charged electrons, including how they affect atomic radius, electronegativity, stability and reactivity.
2. how properties of subatomic particles, including physical location within an atom and their relative size, determine atomic structure, including their identity and charge.
3. and predict patterns in properties that determine how the periodic table is organized based on subatomic particles and element properties (i.e., the arrangement of the main groups of the periodic table reflects the patterns of outermost electrons (i.e. valence electrons).
4. and predict the effects of changing the number of protons, neutrons, and electrons on atomic charges and isotopes of any given element.

Use mathematics and computational thinking:

1. to identify quantifiable relationships between protons, neutrons, and electrons (i.e., using a formula to determine the overall charge of a neutral atom or the atomic mass of the most common isotope).

Instructional Sequence 2
Unit 1: Matter

Az Science Standard Plus HS+C.P1U1.1

Develop and use models to demonstrate how changes in the number of subatomic particles (protons, neutrons, electrons) affect the identity, stability, and properties of the element.

Az Science Standard Essential HS.P1U1.1

Develop and use models to explain the relationship of the structure of atoms to patterns and properties observed within the Periodic Table and describe how these models are revised with new evidence.

Note: Sequence 1 focuses on atoms and elements. Sequence 2 focuses on the Periodic Table and interactions.

CI P1: All matter in the Universe is made of very small particles.

- Several different models of the atom have been proposed throughout history as new evidence has been discovered.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns.
- The repeating patterns of the periodic table reflect patterns of outer electron states.
- The structure and interactions of matter at the bulk scale are determined by forces within and between atoms.

Science and Engineering Practices

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.

Crosscutting Concepts

Patterns:

- Mathematical representations are needed to identify some patterns
- Empirical evidence is needed to identify patterns

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Using Science – U1

- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way

Big Ideas Sequence 2

The model of the atom (atomic theory) has been and is still being modified to explain the behavior of particles. Modifications to the atomic model arise based on new data collected through experiment, quantitative calculations, and new information discovered using technological advancements. Patterns discovered in the periodic table are used to support and develop any modifications.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain and communicate information to explain:

1. how scientists formed previous atomic models and how/why atomic theory changed over time.
    a. Why previous models were rejected.
    b. Describe the current accepted model of the atom.

Develop and use models to make inferences and predict:

2. the patterns of behavior of the elements in the periodic table based on the attraction and repulsion between electrically charged particles and the patterns of outermost electrons that determine the typical reactivity of an atom.
    a. The number and types of bonds formed (i.e. ionic, covalent, metallic) by an element and between elements.
    b. The number and charges in stable ions that form from atoms in a group of the periodic table.
    c. The trend in reactivity and electronegativity of atoms down a group, and across a row in the periodic table, based on attractions of outermost (valence) electrons to the nucleus.
    d. The relative sizes of atoms both across a row and down a group in the periodic table.

Instructional Sequence 3
Unit 1: Matter

Az Science Standard Plus HS+C.P1U1.2

Obtain, evaluate, and communicate the qualitative evidence supporting claims about how atoms absorb and emit energy in the form of electromagnetic radiation.

CI P1: All matter in the Universe is made of very small particles.

- Stable forms of matter are those in which the electric and magnetic field energy is minimized.
- Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths.
- These characteristics allow identification of the presence of an element, even in microscopic quantities.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results.
- Ask questions to determine relationships, including quantitative relationships between independent and dependent variables.

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Planning and Carrying Out Investigations:

- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
- Use investigations to gather evidence to support explanations or concepts.

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.

Engaging in Argument from Evidence:

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

Crosscutting Concepts

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Patterns observable at one scale may not be observable or exist at other scales.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- 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).

Energy and Matter:

- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Using Science – U1

- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.

Big Ideas Sequence 2

Evidence used to identify elements and verify current understanding of the structure of the atom is the absorption and emission of electromagnetic radiation, called spectroscopy. Forms of spectroscopy are used with almost every type of electromagnetic radiation to observe varying physical and chemical properties depending on wavelength.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions that arise from observation to determine:

1. how to identify an element, even in microscopic quantities.

Develop and use models to from investigations to explain:

1. how atoms absorb and emit energy in the form of electromagnetic radiation.
2. how electromagnetic radiation is either absorbed or emitted by different elements.

3. what a nuclear transition is and how it produces gamma rays.

Communicate through scientific writing:

1. how spectroscopy uses the unique combinations and number of bright lines against a dark background to determine an element's identity.

Engage in argument from evidence to explain:

1. how scientific data regarding emission and absorption of energy was used to identify an element.

Unit 2: Interactions of Matter

P1: All matter in the Universe is made of very small particles.
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

Instructional Sequence 1

Az Science Standard Essential HS.P4U1.8

Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings.

Az Science Standard Plus HS+Phy.P4U1.6

Analyze and interpret data to quantitatively describe changes in energy within a system and/or energy flows in and out of a system.

CI P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system.
- That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself as thermal energy.
- "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes.
- Historically, different units and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.

Science and Engineering Practices

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

Planning and Carrying Out Investigations:

- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
- Use investigations to gather evidence to support explanations or concepts.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Engaging in Argument from Evidence:

- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Crosscutting Concepts

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.

Systems and System Models:

- 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.
- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- 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).

Using Science – U1

- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Where factors cannot be experimentally manipulated, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

Big Ideas Sequence 1
All matter in the universe interacts uniquely based on chemical and physical properties. These properties determine how energy is transferred and stored within a system. It's important to consider the conservation of energy throughout any interactions between a system and its surroundings.
Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning. Analyze data using models to determine: 1. what types of energy (i.e., chemical, thermal [endothermic vs. exothermic]) are entering and leaving a system, how energy is transferred and stored, and the validity of the law of conservation of energy. Plan and carry out an investigation using mathematics and computational thinking (e.g., numerical calculations, graphs, or other pictorial depictions of quantitative information): 1. to quantitatively describe changes in energy within a system and/or energy flows in and out of a system. 2. describe that the net change of energy in a system is always equal to the total energy exchanged between system and surroundings. Engage in argument from evidence to argue: 1. that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings. 2. that energy cannot be created nor destroyed. 3. the progression of our understanding of what energy is, how it is defined, and how it is quantified.

Instructional Sequence 2
Unit 2: Interactions of Matter

Az Science Standard Plus HS+C.P1U1.3

Analyze and interpret data to develop and support an explanation for the relationships between kinetic molecular theory and gas laws.

Note: kinetic molecular theory can be used to explain each of the experimentally determined gas laws.

CI P1: All matter in the Universe is made of very small particles.

- Whether or not energy is stored or released can be understood in terms of the collisions of molecules that are matched by changes in kinetic energy.
- Within matter, atoms and their constituents are constantly in motion.
- The arrangement and motion of atoms vary in characteristic ways, depending on the substance and its current state.
- Specifically, atoms in a gaseous state have characteristics and behaviors that vary greatly from the same atoms in a liquid or solid state.
- Temperature and pressure affect such arrangements and motions of particles, as well as the ways in which they interact.

Science and Engineering Practices

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

Planning and Carrying Out Investigations:

- Use investigations to gather evidence to support explanations or concepts
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.

- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Systems and System Models:

- 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.
- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- 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).

Using Science – U1

- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.

Big Ideas Sequence 2

All matter is made of moving particles. Their interactions are governed by the input or export of energy. Temperature, pressure, volume, and quantity of a substance increase or decrease these collisions. These interactions can be quantified by the "gas laws." Gas particles have unique behaviors when compared to behaviors of solids and liquids; these are summarized in the kinetic molecular theory.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use models to explain:

1. characteristics of particles within solids, liquids and gasses such as volume, density, and relative energy.

Plan and carry out investigations to gather, analyze, and interpret data:

1. to measure and determine qualitative and quantitative relationships between characteristics of a system such as temperature, volume, pressure, and number of particles.
2. that evidences Kinetic molecular theory in regard to gas particle behavior including:
    a. Gasses are made of molecules and atoms that move only in straight lines.
    b. Because of how small they are, gasses have negligible volume. For this reason, we consider the volume of the container to be the volume of the gas.
    c. Gas particles move so fast, that there are no attractive or repulsive forces between particles (no intermolecular forces).
    d. Since there are no intermolecular forces, all collisions between particles are completely elastic (no net loss of energy).
    e. Absolute temperature is the average kinetic energy.

Construct an explanation:

1. about how characteristics of a system (i.e., temperature, volume, pressure, and number of particles) interact.

Instructional Sequence 3
Unit 2: Interactions of Matter

Az Science Standard Plus HS+C.P1U1.4

Develop and use models to predict and explain forces within and between molecules.

Az Science Standard Essential HS.P1U1.2

Develop and use models for the transfer or sharing of electrons to predict the formation of ions, molecules, and compounds in both natural and synthetic processes

CI P1: All matter in the Universe is made of very small particles.

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- Stable forms of matter are those in which the electric and magnetic field energy is minimized.
- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and rearrangements of atoms into new molecules, that are matched by changes in kinetic energy.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results.
- Ask questions that require relevant empirical evidence to answer.
- Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

Crosscutting Concepts

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.

Patterns:

- 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.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.

Using Science – U1

- Models provide ways of explaining phenomena in terms of relationships between parts of a system.
- They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 3

Atoms are held together by attractive and repulsive forces. In order to be in their most stable form, atoms will transfer or share electrons. How and why they do this depends on their valence electrons and position on the periodic table.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions about:

1. how an atom will transfer or share electrons to form ions, molecules, and compounds in both natural and synthetic system processes.
    a. Some particles prefer to form certain types of ions, such as cations or anions, to maintain stability.

Develop and use models to predict and explain:

1. forces within and between particles such as intermolecular forces and collision models.
2. the patterns of behavior based on the attraction and repulsion between electrically charged particles and the patterns of outermost electrons that determine the typical reactivity of an atom.
    a. The number and types of bonds formed (i.e. ionic, covalent, metallic) by an element and between elements.
3. How ions, compounds, and molecules are named and classified.

Instructional Sequence 4
Unit 2: Interactions of Matter

Az Science Standard Plus HS+C.P1U1.5

Plan and carry out investigations to test predictions of the outcomes of various reactions, based on patterns of physical and chemical properties.

CI P1: All matter in the Universe is made of very small particles.

- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of rearrangements of atoms into new molecules.
- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results.
- Ask questions that require relevant empirical evidence to answer.
- Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.
- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design.

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- Select appropriate tools to collect, record, analyze, and evaluate data
- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts

Crosscutting Concepts

Patterns:

- 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.
- Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Systems can be designed for greater or lesser stability.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

Big Ideas Sequence 4

In order to obtain the most stable electron arrangement, ions cannot stand alone. Particles rearrange to make new substances in predictable ways. There are variables that affect the rate at which chemical reactions occur. These include temperature, the presence of a catalyst, concentration, pressure, and surface area.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions to make predictions regarding:

1. the products formed as a result of combining two or more substances or inputting energy into a single pure substance.

Plan and carry out investigations to determine:

1. the types of chemical reactions, including how and why certain atoms rearrange in certain patterns (i.e., single replacement, double replacement, synthesis/combination, decomposition, combustion).
2. what variables affect reaction rates such as change in energy, change in entropy, and change in enthalpy.

Unit 3: Changes in Matter

P1: All matter in the Universe is made of very small particles.

Instructional Sequence 1

Az Science Standard HS+C.P1U1.7

Use mathematics and computational thinking to determine stoichiometric relationships between reactants and products in chemical reactions.

Note: Using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products. The Mole. Emphasis is on students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.

CI P1: All matter in the Universe is made of very small particles.

- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Science and Engineering Practices

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
- Create a simple computational model or simulation of a designed device, process, or system.

Planning and Carrying Out Investigations:

- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts.
- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.

Crosscutting Concepts

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time.

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.

Systems and System Models:

- 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.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

Big Ideas Sequence 1

All mass is conserved in a chemical reaction. Stoichiometry utilizes this concept, combined with the molar relationships, in a given reaction to mathematically determine quantities of reactants and/or products in the reaction. Using the mole in combination with the known molar masses of the elements allows predictions of how much product should be made in a reaction, as well as determine the efficiency of a reaction.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use mathematics and computational thinking to calculate:

1. to balance chemical equation(s) and quantify the claim that atoms, and therefore mass, are conserved during a chemical reaction (i.e., stoichiometric calculations to show that the number of atoms or number of moles is unchanged after a chemical reaction where a specific mass of reactant is converted to product).
   a. Molar relationships such as molar mass, molarity, volume of a gas at standard temperature and pressure, and number of particles in a mole.
   b. Molar relationships between reactants and products in a chemical reaction through dimensional analysis.

Plan and carry out investigations:

1. to, within a system, determine the efficiency of a chemical reaction by evaluating percent yield / percent error.

Instructional Sequence 2
Unit 3: Changes in Matter

Az Science Standard HS+C.P1U1.6

Construct an explanation, design a solution, or refine the design of a chemical system in equilibrium to maximize production.

Note: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.

CI P1: All matter in the Universe is made of very small particles.

- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

Science and Engineering Practices

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.
- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects.
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and trade off considerations.

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts.
- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve.

Crosscutting Concepts

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects
- 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.
- Changes in systems may have various causes that may not have equal effects.

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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
- 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.
- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Feedback (negative or positive) can stabilize or destabilize a system.
- Systems can be designed for greater or lesser stability.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- 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).

Using Science – U1

- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.

Big Ideas Sequence 2

When a reaction comes to completion, it is said to be at equilibrium. Some chemical reactions are reversible, which means that the products can be converted back to reactants and the equilibrium is based on the amount of products and reactants present. Le Chatelier's principle is an observation about the equilibrium of chemical reactions. It states that changes in the temperature, pressure, volume, or concentration of a system will result in predictable and opposing changes in the amount of reactants or products. By understanding how changes in these variables will affect a given reaction, we can manipulate the conditions to maximize how much product is produced by that reaction.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Construct an explanation and design a solution to:

1. describe the prioritized criteria and constraints, and quantify each when appropriate (i.e., cost, energy required to produce a product, hazardous nature and chemical properties of reactants and products, and availability of resources).
2. systematically evaluate the proposed refinements to the design of the given chemical system by comparing the redesign to the list of criteria (i.e., increased product) and constraints (e.g., energy required, availability of resources).
3. refine the given designed system by making tradeoffs that would optimize the designed system to increase the amount of product, and describe the reasoning behind design decisions.

Plan and carry out investigations about:

1. identify and describe potential changes in a component of the given chemical reaction system that will cause an increase in the amounts of particular component at equilibrium.
2. to describe the relative quantities of a product before and after changes to a given chemical reaction system (e.g., concentration increases, decreases, or stays the same), and will explicitly use Le Chatelier's principle, including:
    a. how, at a molecular level, a stress involving a change to one component of an equilibrium system affects other components.
    b. changing the concentration of one of the components of the equilibrium system will change the rate of the reaction (forward or backward) in which it is a reactant, until the forward and backward rates are again equal.
    c. a description of a system at equilibrium that includes the idea that both the forward and backward reactions are occurring at the same rate, resulting in a system that appears stable at the macroscopic level.

Unit 4: Nuclear Energy

P1: All matter in the Universe is made of very small particles.

Instructional Sequence 1

Az Science Standard Essential HS.P1U3.4

Obtain, evaluate, and communicate information about how the use of chemistry related technologies have had positive and negative ethical, social, economic, and/or political implications.

CI P1: All matter in the Universe is made of very small particles.

- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.
- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.

Science and Engineering Practices

Asking Questions and Defining Problems:

- Ask questions that require relevant empirical evidence to answer.
- Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design.
- Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts.
- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
- Use investigations to gather evidence to support explanations or concepts.

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.
- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.

- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Crosscutting Concepts

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Changes in systems may have various causes that may not have equal effects.

Using Science – U3

- All innovations consume resources of some kind including financial resources so decisions have to be made when there are competing demands. These decisions, whether at governmental, local or individual level, should be informed by an understanding of the scientific concepts and the technological principles involved.
- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.
- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.

Big Ideas Sequence 1

Chemistry interacts with all sectors of life, particularly in the area of technology. Technology has advanced as understanding of chemistry has evolved over time. No technology comes without its drawbacks and benefits.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Ask questions and define problems to:

1. identify chemistry related technologies and how their relationship to ethical, social, economic and/or political issues in the world.

Plan and carry out investigations to identify:

1. cause and effect relationships between chemical related technologies and how their relationship to ethical, social, economical and/or political issues in the world.

Obtain, evaluate and communicate information to:

1. produce scientific writing and/or oral presentations that integrate multiple sources of information in order to address positive and negative ethical, social, economic, and/or political implications of chemistry related technologies.

Instructional Sequence 2
Unit 4: Nuclear Energy

Az Science Standard Plus HS+C.P1U3.8

Engage in argument from evidence regarding the ethical, social, economic, and/or political benefits and liabilities of fission, fusion, and radioactive decay.

Note: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations, rather than quantitative calculation of energy released.

CI P1: All matter in the Universe is made of very small particles.

- The total number of neutrons plus protons does not change in any nuclear process.
- Strong and weak nuclear interactions determine nuclear stability and processes.
- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present.
- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.
- Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Engaging in Argument from Evidence:

- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Construct a counter-argument that is based on data and evidence that challenges another proposed argument.
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Crosscutting Concepts

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.

- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Patterns observable at one scale may not be observable or exist at other scales.

Using Science – U3

- When designing a new system or product engineers have to take account of ethical values, political and economic realities as well as science and technology.
- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.
- There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues.
- Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion.

Big Ideas Sequence 2

Fusion, fission, and nuclear decay are the most sensitive subjects of discussion in regards to how chemistry and society interact. Fusion is seen in nuclear weapons, fission is a key component in both nuclear weapons and nuclear power, and substances that are radioactive are both positively used in medicine and are problematic leftovers from nuclear power plants and the use of nuclear weapons.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Obtain, evaluate and communicate information to identify:

1. an element by the number of protons and the number of protons and neutrons in the nucleus before and after the decay.
2. the identity of the emitted particles (i.e., alpha, beta — both electrons and positrons, and gamma).
3. the scale of energy changes in a nuclear process is much larger (hundreds of thousands or even millions of times larger) than the scale of energy changes in a chemical process.
4. liabilities and benefits of fission, fusion, and radioactive decay (i.e., radiometric dating, high energy density, radioactive waste, scarcity of strong nuclear material).

Engage in argument from evidence to:

1. critique and evaluate competing arguments about the benefits and liabilities of fission, fusion, and radioactive decay.
2. make and defend a claim about the benefits and liabilities of fission, fusion, and radioactive decay.

Physics
SC81

Scope and Sequence

High School Physics

Physical science encompasses physical and chemical sub-processes that occur within systems. At the high school level, students gain an understanding of these processes at both the micro and macro levels through the intensive study of matter, energy, and forces. Students are expected to apply these concepts to real-world phenomena to gain a deeper understanding of causes, effects, and solutions for physical processes in the real world. The essential standards are those that every high school student is expected to know and understand. Plus standards in chemistry and physics are designed to extend the concepts learned in the essential standards to prepare students for entry level college courses. It is suggested to use the metric system within measurement.

Note:

- The standard number is designed for recording purposes and does not imply instructional sequence or importance.
- In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline.

Unit #	Unit	Standards
1	Newton's Laws, Motion, & Acceleration	**Essential HS.P3U1.6** Collect, analyze, and interpret data regarding the change in motion of an object or system in one dimension, to construct an explanation using Newton's Laws. **Essential HS.P3U2.7** Use mathematics and computational thinking to explain how Newton's laws are used in engineering and technologies to create products to serve human ends.
2	Motion & Centripetal Force	**Plus HS+Phy.P3U1.3** Develop a mathematical model, using Newton's laws, to predict the motion of an object or system in two dimensions (projectile and circular motion).
3	Energy and Energy Conservation	**Essential HS.P4U1.8** Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings. **Essential HS.P4U3.9** Engage in argument from evidence regarding the ethical, social, economic, and/or political benefits and liabilities of energy usage and transfer. **Plus HS+Phy.P4U1.6** Analyze and interpret data to quantitatively describe changes in energy within a system and/or energy flows in and out of a system. **Plus HS+Phy.P4U2.7** Design, evaluate, and refine a device that works within given constraints to transfer energy within a system.
4	Momentum Conservation in a Closed System	**Essential HS.P4U1.8** Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings. **Az Science Standard Plus HS+Phy.P3U1.4**

		Engage in argument from evidence regarding the claim that the total momentum of a system is conserved when there is no net force on the system. **Plus HS+Phy.P3U2.5** Design, evaluate, and refine a device that minimizes or maximizes the force on a macroscopic object during a collision.
5	Gravity and Orbital Motion	**Plus HS+Phy.P3U1.2** Develop and use mathematical models of Newton's law of gravitation and Coulomb's law to describe and predict the gravitational and electrostatic forces between objects. **Essential HS.E2U1.16** Construct an explanation of how gravitational forces impact the evolution of planetary motion, structure, surfaces, atmospheres, moons, and rings. **Essential HS.E2U1.15** Construct an explanation based on evidence to illustrate the role of nuclear fusion in the life cycle of a star. **Essential HS.E2U1.17** Construct an explanation of the origin, expansion, and scale of the universe based on astronomical evidence.
6	Electricity and Magnetism	**Essential HS.P2U1.5** Construct an explanation for a field's strength and influence on an object (electric, gravitational, magnetic). **Plus HS+Phy.P4U1.8** Use mathematics and computational thinking to explain the relationships between power, current, voltage, and resistance. **Plus HS+Phy.P2U1.1** Plan and carry out investigations to design, build, and refine a device that works within given constraints to demonstrate that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
7	Waves: Mechanical, Sound, and Electromagnetic	**Essential HS.P4U1.10** Construct an explanation about the relationships among the frequency, wavelength, and speed of waves traveling in various media, and their applications to modern technology.

P3: Changing the movement of an object requires a net force to be acting on it.

Instructional Sequence 1

Az Science Standard Essential HS.P3U1.6

Collect, analyze, and interpret data regarding the change in motion of an object or system in one dimension, to construct an explanation using Newton's Laws.

Az Science Standard Essential HS.P3U2.7

Use mathematics and computational thinking to explain how Newton's laws are used in engineering and technologies to create products to serve human ends.

Note: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.

CI P3 Changing the movement of an object requires a net force to be acting on it.

- Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light.
- The application of science in making new materials is an example of how scientific knowledge has led advances in technology and provided engineers with a wider choice in designing constructions.
- At the same time technological advances have helped scientific developments by improving instruments for observation and measuring, automating processes that might otherwise be too dangerous or time consuming to undertake, and particularly through the provision of computers.
- Thus, technology aids scientific advances which in turn can be used in designing and making things for people to use.

Science and Engineering Practices

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Select appropriate tools to collect, record, analyze, and evaluate data.
- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
- Use investigations to gather evidence to support explanations or concepts.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
- Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.
- Create a simple computational model or simulation of a designed device, process, or system.

Crosscutting Concepts

Patterns:

- 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.
- 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.
- Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.
- 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.

Scale, Proportion, and Quantity:

- 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).

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.

- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Using Science – U2

- Technological advances have helped scientific developments by improving instruments for observation and measuring, automating processes that might otherwise be too dangerous or time consuming to undertake, and particularly through the provision of computers.
- Technology aids scientific advances which in turn can be used in designing and making things for people to use.
- The application of science in designing and making new tools and machines has made mass production possible so more people have access to a range of commodities.
- There are disadvantages as well as advantages to some technological products.

Big Ideas Sequence 1

For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first but in the opposite direction (Newton's third law). At the macroscale, the motion of an object subject to forces is governed by Newton's second law of motion. Under everyday circumstances, the mathematical expression of this law in the form $F_{net}/m=a$ accurately predicts changes in the motion of a single macroscopic object of a given mass due to the total force on it.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Plan and carry out an investigation:

1. using net force to determine acceleration in order to construct an explanation of Newton's laws.
    a. A more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration.
    b. The result of the force of gravity in isolation is a constant acceleration on macroscopic objects as evidenced by the fact that the ratio of net force to mass remains constant.
2. to gather empirical evidence of patterns to distinguish between causal and correlational relationships linking force, mass, and acceleration in a system.

Analyze and interpret data using mathematical thinking:

1. to describe the relationship between the observed quantities is expressed in data by the formula $a = Fnet/m$ (e.g., double force yields double acceleration, etc.).
2. to express the relationship $Fnet=ma$ in terms of causality, namely that a net force on an object causes the object to accelerate.
3. to explain how data based on Newton's laws has provided engineers with physical, mathematical, and computer models to use in the construction of products to serve human needs.

Unit 2: Motion & Centripetal Force

P3: Changing the movement of an object requires a net force to be acting on it.

Instructional Sequence 1

Az Science Standard Plus HS+Phy.P3U1.3

Develop a mathematical model, using Newton's laws, to predict the motion of an object or system in two dimensions (projectile and circular motion).

CI P3 Changing the movement of an object requires a net force to be acting on it.

- Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light.

Science and Engineering Practices

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.
- Develop a complex model that allows for manipulation and testing of a proposed process or system.
- Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.
- Create a simple computational model or simulation of a designed device, process, or system.

Crosscutting Concepts

Systems and System Models:

- 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.
- 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.
- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Systems can be designed for greater or lesser stability.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

A projectile is an object upon which the only force acting is gravity. It has both a horizontal and vertical component. Similarly, an object moving in a circle is experiencing acceleration and multiple components of force, including inward, normal, and sometimes gravitational. Even if moving at a constant speed, there is still a change in velocity due to the change in direction, and therefore an acceleration.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop a mathematical model to:

1. explore the independence of horizontal and vertical motion of projectiles, and how a net force from gravity accelerates a projectile vertically.
2. predict the motion of an object in uniform circular motion and how a net force must be acting inwardly (centripetal force) on the object.
3. accurately predict changes in motion with respect to projectiles, falling objects and objects traveling in a circular path and their behavior in a system.
4. support explanations of relationships between net forces and motion.

Unit 3: Energy & Energy Conservation

P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

Instructional Sequence 1

Az Science Standard Essential HS.P4U1.8

Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings.

Az Science Standard Essential HS.P4U3.9

Engage in argument from evidence regarding the ethical, social, economic, and/or political benefits and liabilities of energy usage and transfer.

Az Science Standard Plus HS+Phy.P4U1.6

Analyze and interpret data to quantitatively describe changes in energy within a system and/or energy flows in and out of a system.

Az Science Standard Plus HS+Phy.P4U2.7

Design, evaluate, and refine a device that works within given constraints to transfer energy within a system.

CI P4 The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- "Mechanical energy" generally refers to some combination of motion and stored energy in an operating machine.
- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.
- Across the world, the demand for energy increases as human populations grow and because modern lifestyles require more energy, particularly in the convenient form of electrical energy.
- Fossil fuels, frequently used in power stations and generators, are a limited resource and their combustion contributes to global warming and climate change.
- Therefore, other ways of generating electricity have to be sought, whilst reducing demand and improving the efficiency of the processes in which we use it.

Science and Engineering Practices

Analyzing and Interpreting Data:

- Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

- Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

Engaging in Argument from Evidence:

- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Construct a counter-argument that is based on data and evidence that challenges another proposed argument.
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.
- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects.
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and trade off considerations.

Crosscutting Concepts

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.
- 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.

Scale, Proportion, and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Patterns observable at one scale may not be observable or exist at other scales.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

- 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).

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Systems can be designed for greater or lesser stability.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Using Science – U2

- Science, engineering and technology are closely inter-connected. The application of science in making new materials is an example of how scientific knowledge has led advances in technology and provided engineers with a wider choice in designing constructions.
- Often in the past technological products have been developed empirically in advance of scientific ideas.
- The application of science in designing and making new tools and machines has made mass production possible so more people have access to a range of commodities.
- There are disadvantages as well as advantages to some technological products.

Using Science – U3

- All innovations consume resources of some kind including financial resources so decisions have to be made when there are competing demands. These decisions, whether at governmental, local or individual level, should be informed by understanding of the scientific concepts and the technological principles involved.
- When designing a new system or product engineers have to take account of ethical values, political and economic realities as well as science and technology.
- Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require ethical and moral judgements which are not provided by knowledge of science.

Big Ideas Sequence 1

Energy is conserved in a closed system. In a closed system the energy an object has may be transferred from one energy store to another. Energy may be transferred into or out of a system by its surroundings. Society depends on a variety of energy resources including fossil fuels, nuclear, hydro, and renewable energies. Energy is neither created nor destroyed.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Design, evaluate, and refine a device:

1. that converts energy from one form to another.

   a. Specify the initial and final forms of energy (i.e., electrical energy, motion, light).
   b. Predict mathematically how conservation of energy will affect system behavior.
   c. Identify the device by which the energy will be transformed (i.e., a light bulb to convert electrical energy into light energy, a motor to convert electrical energy into energy of motion).
2. given criteria and constraints which include:
   a. the initial and final forms of energy.
   b. description of how the device functions to transfer energy from one form to another.
   c. the materials available for the construction of the device.
   d. safety considerations.
   e. the ethical, social, economic, and/or political benefits and liabilities
3. to determine how well it meets the specified criteria and constraints of the problem by using the results of the test and address problems in the design or improve its functioning.

Analyze and interpret data:

1. from simulations (i.e., PhET) and student led investigation (may include designed device data if applicable) that quantitatively measures the energy transfer from kinetic to potential and potential to kinetic.
2. to show changes of energy in a system can be described in terms of energy flows into, out of, and within that system (some energy is lost to the environment).

Engage in argument from evidence:

1. developed from student led investigations, that the total energy is conserved in a closed system, and that energy is transferred from one object to another in a system.
2. about the positive and negative economic, social, ethical and political implications of the demand for energy as human populations grow and in the use of fossil fuels as a limited resource.

MESA PUBLIC SCHOOLS
MESA, ARIZONA

Unit 4: Momentum Conservation in a Closed System

P3: Changing the movement of an object requires a net force to be acting on it.
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

Instructional Sequence 1

Az Science Standard Essential HS.P4U1.8

Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings.

Note: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.

Az Science Standard Plus HS+Phy.P3U1.4

Engage in argument from evidence regarding the claim that the total momentum of a system is conserved when there is no net force on the system.

Az Science Standard Plus HS+Phy.P3U2.5

Design, evaluate, and refine a device that minimizes or maximizes the force on a macroscopic object during a collision.

Note: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.

P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

CI P3 Changing the movement of an object requires a net force to be acting on it.

- Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light.
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
- In any system, total momentum is always conserved.
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.
- The application of science in making new materials is an example of how scientific knowledge has led advances in technology and provided engineers with a wider choice in designing constructions.

Science and Engineering Practices

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
- Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world.
- Create a simple computational model or simulation of a designed device, process, or system.

Engaging in Argument from Evidence:

- Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
- Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
- Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.
- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects.
- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Crosscutting Concepts

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.

Patterns:

- Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Systems and System Models:

- Systems can be designed to do specific tasks.
- 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.
- 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.
- 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.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Systems can be designed for greater or lesser stability.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- A scientific theory is a well substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and so become well established.
- If new data do not fit current ideas then the ideas have to be changed or replaced by alternative ideas.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Using Science – U2

- Technology aids scientific advances which in turn can be used in designing and making things for people to use.
- The application of science in designing and making new tools and machines has made mass production possible so more people have access to a range of commodities.

Big Ideas Sequence 1

Momentum is defined as $p=mv$. The system momentum before a collision is equal to the system momentum after the collision, where system momentum is constant. Impulse is the change in momentum of an object when the object is acted upon by a net force for an interval of time. The total momentum of a system after a collision remains zero, but there are different types of collisions (elastic and inelastic).

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Use mathematics and computational thinking:

1. to predict reasonable outcomes about the changes in energy that occur after objects collide, based on patterns linking object collision and energy transfer between objects and the surrounding air.
2. to describe the changes to momentum ($p=mv$) during a collision.

Engage in argument:

1. and explain using evidence from scientific investigations that the momentum of a system is conserved in a closed system, and that the total momentum of a system can change when the system interacts with objects outside itself.
2. that identifies and describes evidence that supports the claims that:
    a. when the kinetic energy of an object changes, energy is transferred to or from that object.
    b. based on changes in the observable features of the object (i.e., motion, temperature), the kinetic energy of the object has changed.

Design a device:

1. to minimize or maximize a force on an object during a collision.
2. and evaluate its design using:

   a. a qualitative measure of energy (e.g., relative motion, relative speed, relative brightness) of the object before the collision.
   b. the transfer of energy by contact forces between colliding objects that results in a change in the motion of the objects.
   c. the transfer of energy to the surrounding air when objects collide resulting in sound and heat.

3. and refine its design:
   a. based on observable changes in features of other objects or the surroundings in the defined system.
   b. by making tradeoffs that would optimize the device to better minimize or maximize the force impact.

Unit 5: Gravity & Orbital Motion

P2: Objects can affect other objects at a distance.
P3: Changing the movement of an object requires a net force to be acting on it.
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

Instructional Sequence 1

Az Science Standard Plus HS+Phy.P3U1.2

Develop and use mathematical models of Newton's law of gravitation and Coulomb's law to describe and predict the gravitational and electrostatic forces between objects.

Note: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.

Az Science Standard Essential HS.P2U1.5

Construct an explanation for a field's strength and influence on an object (~~electric~~, gravitational, ~~magnetic~~).

Az Science Standard Essential HS.E2U1.16

Construct an explanation of how gravitational forces impact the evolution of planetary motion, structure, surfaces, atmospheres, moons, and rings.

Az Science Standard Essential HS.E2U1.15

Construct an explanation based on evidence to illustrate the role of nuclear fusion in the life cycle of a star.

Az Science Standard Essential HS.E2U1.17

Construct an explanation of the origin, expansion, and scale of the universe based on astronomical evidence.

CI P3: Changing the movement of an object requires a net force to be acting on it.

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles).
- At the macroscopic scale, energy manifests itself in multiple phenomena, such as motion, light, sound, electrical and magnetic fields, and thermal energy.

CI P2: Objects can affect other objects at a distance.

- Newton's law of universal gravitation provide the mathematical models to describe and predict the effects of gravitational forces between distant objects.
- Forces at a distance are explained by fields permeating space that can transfer energy through space.
- A field is the region of the object's influence around it, the strength of the field decreasing with distance from the object.
- Another object entering this field experiences an effect – attraction or repulsion.
- Gravity, electric, and magnetic interactions can be described in terms of fields.

CI E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

- The solar system consists of the sun and a collection of objects of varying sizes and conditions—including planets and their moons—that are held in orbit around the sun by its gravitational pull on them.

- This system appears to have formed from a disk of dust and gas, drawn together by gravity.
- Earth and the moon, sun, and planets have predictable patterns of movement.
- These patterns, which are explainable by gravitational forces and conservation laws, in turn explain many large-scale phenomena observed on Earth.
- The source of energy that the Sun and all stars radiate comes from nuclear reactions in their central cores.
- The Sun is one of millions of stars that together make up a galaxy called the Milky Way.
- The next nearest star is much further away than the distance of the furthest planet, Neptune.
- The distances between and within galaxies are so great that they are measured in light years, the distance that light can travel in a year.
- There are billions of galaxies in the universe, almost unimaginably vast distances apart and perceived as moving rapidly away from each other.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Developing and Using Models:

- Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations.
- Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems.
- Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Scale, Proportion and Quantity:

- The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

- Patterns observable at one scale may not be observable or exist at other scales.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.
- 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).

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.
- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Patterns:

- 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.
- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Structure and Function:

- 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.

Using Science – U1

- Where factors cannot be experimentally manipulated, as in the case of the movement of planets in the solar system, a phenomenon can be investigated by observing systematically on several occasions and over a period of time.
- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- Models provide ways of explaining phenomena in terms of relationships between parts of a system. They are developed through an iterative process of comparing what they predict with what is found in the real world.
- Scientific explanations account for specific events or phenomena in terms of a theory or model.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.
- Although there is greater confidence in ideas or models that leads to predictions that are repeatedly and reliably confirmed by evidence – and so become regarded as facts – an explanation or theory can never be proved 'correct' because there is always the possibility of further data conflicting with it or because a new theory is found that also provides a good explanation.

Big Ideas Sequence 1

Newton's Law of Universal Gravitation describes the mutual attraction between two objects. This gravitational force between objects is dependent on the distance between them and has an inverse squared relationship. Gravitational forces between masses are responsible for the creation of stars and planets. Orbital motion is described as the movement of a satellite around a larger body with the force of gravity being the centripetal force acting on the satellite keeping it in circular motion.

Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. The electrostatic force between two objects is described as the product of their individual charges divided by the separation distance squared ($F_e = kq_1q_2/d^2$), where a negative force is understood to be attractive.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Develop and use a (mathematical) model:

1. to identify and describe the gravitational attraction between two objects as the product of their masses divided by the separation distance squared ($F_g = -G\, m_1m_2/d^2$), where a negative force is understood to be attractive, and only predicts an attractive force because mass is always positive.
2. to identify and describe the electrostatic force between two objects as the product of their individual charges divided by the separation distance squared ($F_e = k\, q_1q_2/d^2$), where a negative force is understood to be attractive, and predicts both attraction and repulsion because electric charge can be either positive or negative.
3. to predict the gravitational force between objects (and the effects on planetary motion) or predict the electrostatic force between charged objects.
4. to describe that the ratio between gravitational and electric forces between objects with a given charge and mass is a pattern that is independent of distance.
5. to describe that the change in the energy of objects interacting through electric or gravitational forces depends on the distance between the objects.
6. to observe forces, through simulations, of interactions between distant objects, explained by fields transferring energy through space.

Construct an explanation:

1. about why smaller objects orbit around larger objects in predictable patterns.
2. how gravitational forces cause planets' structures to be spherical, hold atmospheres, and have orbiting bodies, due to:
    a. gravity affects planetary motion.
    b. gravity causes large structures to become spherical.
    c. surface processes are affected by gravity (i.e., erosion, weathering, and deposition).
    d. a planet's gravity holds other matter in place (i.e., its atmosphere, its rings and its moons).
3. of the origin and scale of the universe based on astronomical evidence by understanding the expansion of the universe according to Hubble's law using red shift concepts (as indicated by the redshifts of galaxies), discovery and measurement of the cosmic microwave background, and the relative abundances of light elements produced by Big Bang.
    a. Redshifts indicate that an object is moving away from the observer, thus the observed redshift for most galaxies and the redshift vs. distance relationship is evidence that the universe is expanding.
    b. The observed background cosmic radiation and the ratio of hydrogen to helium have been shown to be consistent with a universe that was very dense and hot a long time ago and evolved through different stages as it expanded and cooled (i.e., the formation of nuclei from colliding protons and neutrons predicts the hydrogen-helium ratio *(numbers not expected from students)*, later formation of atoms from nuclei plus electrons, background radiation was a relic from that time).
4. to illustrate the role of nuclear fusion in the life of a star by understanding how the atoms (the element hydrogen in the case of our Sun) inside the star collide together, fueling the process of nuclear fusion, which generates heat, electromagnetic radiation (including visible light), and energy in other forms, such as high-energy particles (and Helium, and the case of our Sun).

Unit 6: Electricity & Magnetism

P2: Objects can affect other objects at a distance.
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

Instructional Sequence 1

Az Science Standard Essential HS.P2U1.5

Construct an explanation for a field's strength and influence on an object (electric, ~~gravitational~~, magnetic).

Az Science Standard Plus HS+Phy.P4U1.8

Use mathematics and computational thinking to explain the relationships between power, current, voltage, and resistance.

Az Science Standard Plus HS+Phy.P2U1.1

Plan and carry out investigations to design, build, and refine a device that works within given constraints to demonstrate that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

CI P2 Objects can affect other objects at a distance.

- Coulomb's law provide the mathematical models to describe and predict the effects of electrostatic forces between distant objects.
- Forces at a distance are explained by fields permeating space that can transfer energy through space.
- Magnets or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
- Some cases of action at a distance are not explained in terms of radiation from a source to a receiver.
- A magnet, for example, can attract or repel another magnet and both play equal parts.
- Similarly, the attraction and repulsion between electric charges is reciprocal.
- A field is the region of the object's influence around it, the strength of the field decreasing with distance from the object.
- Another object entering this field experiences an effect – attraction or repulsion.
- Gravity, electric and magnetic interactions can be described in terms of fields.

CI P4 The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

Science and Engineering Practices

Planning and Carrying Out Investigations:

- Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

- Select appropriate tools to collect, record, analyze, and evaluate data.
- Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts.
- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
- Use investigations to gather evidence to support explanations or concepts.

Using Mathematics and Computational Thinking:

- Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
- Create a simple computational model or simulation of a designed device, process, or system.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.
- Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects.

Crosscutting Concepts

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable.
- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.
- Systems can be designed for greater or lesser stability.

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
- 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.
- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.

Using Science – U1

- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.

- A correlation cannot usually be taken as conclusive evidence that change in one factor is the cause of the change in the other. Finding that one thing is the cause of an effect is not the same as explaining the mechanism by which the effect is brought about.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.
- Explanations do not emerge self-evidently from data but are created in a process that often involves intuition, imagination and informed hypothesis.

Big Ideas Sequence 1

A field is the region of the object's influence around it, the strength of the field decreasing with distance from the object. Another object entering this field experiences an effect – attraction or repulsion. Gravity, electric, and magnetic interactions can be described in terms of fields. Electric, magnetic and gravitational forces can be predicted by how an object will be affected by being placed in a corresponding field (i.e., mass in a gravitational field, charges in an electric field). Power, current, voltage and resistance all contribute to the production of an electric current that produces a magnetic charge, and vice versa.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Plan and Carry out Investigations to design, build, and refine a device that works within given constraints:

1. that will produce a magnetic field and that a changing magnetic field can produce an electric current. (Possible materials: coil/solenoid, Strong magnet that will fit in coil/solenoid, Galvanometer)
2. to observe an electric current in the circuit that is uniquely related to the presence of a changing magnetic field near the circuit and describe why these effects seen must be causal and not correlational, citing specific cause-effect relationships.
3. with minimal guided information, to determine if electricity can create an electromagnet. (Possible materials: coil, battery, paperclips)

Use mathematics and computational thinking:

1. during student led investigations to explore how resistance controls current flow (cause and effect) in circuits.
2. solve for an unknown variable (current, voltage, resistance, power) in a series and/or parallel circuit problem.

Construct an explanation:

1. that describes a field's strength using evidence from observations (various: experiments, simulations) that fields permeating space transfer energy.
2. by developing models of how an electric field is the region of an object's influence around it, and that the strength of the field decreases with distance from the object.

Unit 7: Waves

P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

Instructional Sequence 1

Az Science Standard Essential HS.P4U1.10

Construct an explanation about the relationships among the frequency, wavelength, and speed of waves traveling in various media, and their applications to modern technology.

Note: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.

CI P4 The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.
- The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties.
- Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.
- Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency.
- Structures have particular frequencies at which they resonate.
- This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments.
- All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat).
- Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.
- Photovoltaic materials emit electrons when they absorb light of a high-enough frequency.
- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research.
- They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.
- Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communications, and information technologies. *(Note: Details of quantum physics are not formally taught at this grade level.)*

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information:

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

Constructing Explanations and Designing Solutions:

- Make quantitative and qualitative claims regarding the relationship between dependent and independent variables.
- Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion.

- Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review.
- Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

Crosscutting Concepts

Patterns:

- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns

Stability and Change:

- Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.
- Systems can be designed to cause a desired effect.
- Changes in systems may have various causes that may not have equal effects.

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved.
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- Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.
- Energy drives the cycling of matter within and between systems.

Using Science – U1

- Looking for patterns in the data may reveal that there is a correlation between factors – as one factor changes, so does another in a regular way.
- A correlation may be used to propose a hypothesis, which can be used to make predictions, even though it may involve aspects that cannot be directly observed or changed.
- It is the coherence of all hypotheses consistent with all known facts and scientific principles which provides the best possible explanation.

Big Ideas Sequence 1

Wave motion is the transfer of energy between particles in a medium. The velocity of a wave is dependent on the medium that it is passing through. For all waves, the velocity may be found by multiplying the waves frequency with its wavelength. Modern applications of waves include: data transfer through fiber optic cables, medical orthopedic operations done using fiber optic cables, cellular communication using e/m waves.

Evidence of Learning Specifications: how students show proficiency in standards through engaging with phenomena and 3D learning.

Construct an explanation:

1. about the mathematical relationship among the frequency, wavelength and speed of waves traveling in various media and applications in modern technology by successfully understanding:

a. the wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

b. the product of the frequency and the wavelength of a particular type of wave in a given medium is constant, and this relationship is the wave speed mathematically expressed by $v = f\lambda$.

c. waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information that can be digitized and used in computer applications.

d. how structures have specific frequencies at which they resonate (i.e., vocal cords and musical instruments).

e. the absorption of photons and production of electrons for devices that rely on the photoelectric effect, and how the basic physics principles were utilized in the research and development of this function.

2. predicting mathematically the relative change in the wavelength of a wave when it moves from one medium to another in terms of cause (different media) and effect (different wavelengths but same frequency).
3. from evidence (various sources) that all electromagnetic radiation travels through a vacuum at the speed of light.
4. that explain how long wavelengths of electromagnetic radiation is usually converted to heat, (the total energy given off and received is conserved and will be the same amount); conversely, short wavelengths can ionize atoms causing damage to cells.

Bibliography

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