Glendale Unified School District

High School

January 19, 2021

Department:	Science
Course Title:	Chemistry in the Earth System
Course Code:	7110/7111
Grade Level(s):	9-12
School(s) Course Offered:	Crescenta Valley High School, Clark Magnet High School, Glendale High School, Hoover High School
UC/CSU Approved (Y/N, Subject):	Yes, (D) Science
Course Credits:	10
Recommended Prerequisite:	Concurrent with Mathematics - Integrated I or higher
Recommended Textbook:	California HMH Science Dimensions – Chemistry in the Earth System (2020)
Course Overview:	Chemistry in the Earth System is a lab science course based upon the California Next Generation Science Standards (CA NGSS), authentically integrating Earth and space science content with physical science when applicable. The Disciplinary Core Ideas addressed are Matter and its Interactions, Waves and their Applications in Technologies for Information Transfer, Energy, Earth's Systems, and Earth and Human Activity. Additionally, the course includes Engineering Design and Links Among Engineering, Technology, Science, and Society.

First Semester-Course Content

Unit 1: **Measuring Matter and Energy** *(5 weeks)*

A. In this unit, students learn how to measure with precision, perform calculations, and determine the amount of energy contained in foods. They will plan and carry out an investigation to explore the properties of matter and analyze how chemical engineers optimize system processes. Based on their findings, they will construct explanations about how properties of materials influence the way the materials are used. The following are the guiding questions of the unit. What is energy, how is it measured, and how does if flow within a system? What mechanisms allow us to utilize the energy of our food and fuels?
   - The learning experiences in this unit prepare students for mastery of the following performance expectations:
     - HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
     - HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
     - HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
     - HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
   - The learning experiences in this unit prepare students for mastery of the following Environmental Principles and Concepts:
     - Principle 1: People Depend on Natural Systems
     - Principle 2: People Influence Natural Systems
     - Principle 3: Natural Systems Change in Ways that People Benefit From and Can Influence
     - Principle 5: Decisions Affecting Resources and Natural Systems are Complex and Involve Many Factors

B. Lessons
   - Lesson 1 – In this lesson, students explore energy in an everyday chemical process by performing an experiment in which they measure the changes in energy content of food samples and then analyze and interpret data **(SEP Developing and Using Models, DCI PS3.A, CCC Energy and Matter)**. Students will use their knowledge of chemical properties of substances **(DCI PS1.B)** as well as dimensional analysis **(SEP Using Mathematical and Computational Thinking)** to analyze data using SI Units of measurement **(CCC Patterns)**. Students use the kinetic model to explore the transfer of energy in everyday processes and consider

how energy and matter move in and out of systems **(SEP Developing and Using Models, DCI PS3.A)**. Students end the lesson by performing calculations involving conversion factors and analyzing data using significant figures and scientific notation **(SEP Analyze and Interpret Data, DCI PS1.B, CCC Energy and Matter)**.

- Lesson 2 – In this lesson, students will learn that the energy and matter of a system depends on the motion and interaction of matter within a system, and they will relate this concept to different states of matter **(DCI PS1.A, CCC Energy and Matter)**. They will plan and conduct an investigation in which they explore different types of mixtures **(SEP Planning and Carrying Out Investigations)**. They will look for patterns in the mixtures that enable them to identify ways of separating the parts **(CCC Patterns)**. Students will use models to learn about systems and to predict the behavior of systems **(CCC Systems and System Models)**. They will learn about the engineering design process by evaluating a solution to a complex real-world problem while considering criteria and constraints, including requirements set by society **(SEP Constructing Explanations and Designing Solutions, DCI ETS1.A, ETS1.B)**.

Unit 2: **<u>Heat and Energy in the Earth System</u>** (*6 weeks)*

A. In this unit, students will investigate heat and other forms of energy in the Earth system. They will investigate a phenomenon in which water exists in three different states in the same area and explore how energy flowing in systems causes changes in motion of the particles within those systems. They will use models to learn about the flow of energy through systems and gather evidence to develop a model of Earth's interior that explains how energy flows inside Earth. Then, they will construct an explanation for how energy is transferred inside Earth.
   - The learning experiences in this unit prepare students for mastery of the following performance expectations:
     - HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
     - HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
     - HS-PS3-4: Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
     - HS-ESS2-3: Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.
     - HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and

constraints on interactions within and between systems relevant to the problem.

- The learning experiences in this unit prepare students for mastery of the following Environmental Principles and Concepts:
  - Principle 4: There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing Between Systems

B. Lessons

- Lesson 1 – In this lesson, students will explore a working definition of energy that manifests itself as thermal energy **(DCI PS3.A)**. They will plan and conduct an investigation to explore the properties of gases **(SEP Planning and Carrying Out Investigations)** and describe a system and its boundaries using models **(CCC Systems and System Models)**. Students will develop models **(SEP Developing and Using Models)** to explain changes in state and to illustrate the relationships between systems and between components of a system. Finally, students will recognize that energy can move from one place to another or between systems **(CCC Energy and Matter)** and is a quantitative property of a system that depends on the motion and interactions of matter **(DCI PS3.A)**.
- Lesson 2 – In this lesson, students ask questions and define problems to analyze the flow of energy in systems (**SEP Asking Questions and Defining Problems)**. While analyzing the flow of energy in systems, students develop and use models and the boundaries of systems to illustrate and predict relationships **(SEP Developing and Using Models, CCC Systems and System Models)**. Students investigate energy and how it is transformed and transferred in systems **(DCI PS3.A, PS3.B, CCC Energy and Matter)**.
- Lesson 3 – In this lesson, students will develop and use models **(SEP Developing and Using Models)** to illustrate relationships between components of a system, using evidence from deep probes and seismic waves **(DCI ESS2.A)**. Students show how empirical evidence and patterns of evidence explain motion of the mantle and plates through thermal convection **(DCI ESS2.A)** and how energy drives the cycling of matter within systems **(CCC Energy and Matter)**. They develop an understanding of the physical and chemical processes that lead to a model of Earth with a hot but solid Inner core, a liquid outer core, and a solid mantle and crust **(DCI ESS2.A)**. They learn how scientists develop and use models **(SEP Developing and Using Models)** that involve scientists and engineers. Students learn that motion of the plates occurs through thermal convection and gravitational movement **(DCI ESS2.A)**. They develop a model to illustrate the relationships between components of a system and to explain how energy drives the cycling of matter within systems **(CCC Energy and Matter)**.

Unit 3: **Patterns in the Properties of Matter** (6 *weeks)*

A. In this unit, students investigate the particles of matter more closely, exploring how x-rays are able to show differences between bones and soft tissues. They will also explore how atomic structure relates to the patterns in the properties of matter seen in the periodic table and how they can use an understanding of atomic structure to make predictions about the behavior of elements. They will gather evidence about the properties of chemical compounds and explain how these properties are related to atomic structure.

- The learning experiences in this unit prepare students for mastery of the following performance expectations:
  - HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
  - HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
  - HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
  - HS-PS4-3: Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.
- The learning experiences in this unit prepare students for mastery of the following Environmental Principles and Concepts:
  - Principle 1: People Depend on Natural Systems
  - Principle 2: People Influence Natural Systems

B. Lessons

- Lesson 1 – In this lesson, students learn about the development of models **(SEP Developing and Using Models)** that represent the structure of atoms on a comprehensible scale **(CCC Scale, Proportion, and Quantity)**. Students learn that an atom has a charged substructure, consisting of a nucleus, which is made of protons and neutrons **(DCI PS1.A)**. Students also learn to evaluate evidence and reasoning behind currently accepted explanations of observable phenomena related to atomic structures **(SEP Engaging in Argument from Evidence)**.
- Lesson 2 – In this lesson, students explore patterns in the periodic table **(CCC Patterns)** and use them to make predictions about the properties of elements **(DCI PS1.A, DCI PS1.B)**. Students construct explanations about how the periodic table orders elements and how the elements behave in chemical bonds **(SEP Constructing Explanations and Designing Solutions, DCI PS1.A, DCI PS1.B)**. They model Mendeleev's process for the development of the periodic table by arranging colored paint chip cards based on different patterns, using these patterns to find missing cards **(CCC Patterns)**. Students examine the periodic table to learn how ionization energies, atomic radii, electronegativities, and number of outer electrons relate to an element's position on the periodic table **(SEP Constructing Explanations and Designing Solutions, DCI PS1.A, CCC Patterns)**. They construct explanations to explain how atomic structure influences these trends **(SEP Developing and Using Models, SEP Constructing Explanations and Designing Solutions, DCI PS1.A, DCI PS1.B)**.

- In this lesson, students will carry out an investigation in which they relate the structures of compounds to their melting points **(SEP Planning and Carrying Out Investigations, DCI PS1.A)**. Students will learn about electronegativity, which measures forces of attraction and repulsion between electric charges at the atomic scale, and will relate those forces to structure and interactions of matter at the bulk scale **(DCI PS1.A)**. Then, students will use the concept of electronegativity to carry out an investigation of the periodic table and explore how it reveals patterns that provide evidence for causality in explanations of phenomena that they can observe in bulk materials **(SEP Planning and Carrying Out Investigations, CCC Patterns)**. Students will use data on the periodic table to serve as the bases for evidence about patterns of phenomena **(CCC Patterns)**. Students learn that these patterns demonstrate that the structure and forces within and between atoms **(DCI PS1.A)**.

Second Semester-Course Content

Unit 4: **<u>Chemical Attractions</u>** (*6 weeks)*

A. In this unit, students construct explanations about how interactions between particles affect both the macroscopic properties of a material and how they interact with other particles. They will explore material properties and design. They will explore engineering with polymers and construct explanations about cycles of matter in chemical reactions and about how these reactions can be observed and quantified. They will also investigate how intermolecular forces influence the properties of solutions.
   - The learning experiences in this unit prepare students for mastery of the following performance expectations:
     - HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
     - HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
     - HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
     - HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*
     - HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
   - The learning experiences in this unit prepare students for mastery of the following Environmental Principles and Concepts:
     - Principle 1: People Depend on Natural Systems
     - Principle 2: People Influence Natural Systems

- Principle 4: There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing Between Systems

B. Lessons
- Lesson 1 – In this lesson, students will develop and use models based on evidence **(SEP Developing and Using Models)** to show that structure and interactions of matter at the bulk scale are determined by electric forces within and between atoms **(DCI PS1.A, CCC Structure and Function)**. Students will use the knowledge of forces of attraction and repulsion between electric charges at the atomic scale **(DCI PS2.B)** to conduct investigations to produce data that serve as the basis for evidence **(SEP Planning and Carrying Out Investigations)**. These investigations can provide evidence for causality in explanations of phenomena **(CCC Patterns)**.
- Lesson 2 – In this lesson, students will use mathematical representations **(SEP Using Mathematical and Computational Thinking)** to show that atoms are conserved and their properties can be used to predict chemical reactions **(DCI PS1.B, CCC Energy and Matter)**. Students will use the organization of atoms on the periodic table **(DCI PS1.A)** to construct explanations based on reliable evidence that supports the concept that theories and laws describe how the chemical reactions occur today as they would have in the past and will in the future **(SEP Constructing Explanations and Designing Solutions**). These explanations of chemical reactions can provide evidence for causality in explanations of phenomena **(CCC Patterns)**.
- Lesson 3 – In this lesson, students will plan and conduct an investigation **(SEP Planning and Carrying Out Investigations)** to explore patterns of conductivity in solutions **(CCC Patterns)** and relate their observations to electrical forces within and between atoms **(DCI PS1.A)**. Students will use mathematics and computational thinking **(SEP Mathematics and Computational Thinking)** to describe the concentration of solutions and relate patterns **(CCC Patterns)** in solubility to forces within and between atoms **(DCI PS1.A)**. Finally, students will construct explanations **(SEP Constructing Explanations and Designing Solutions)** of how chemical properties of solutions **(DCI PS1.B)** are determine by patterns **(CCC Patterns)** of forces within and between atoms.

Unit 5: <u>**Reaction Energy**</u> *(4 weeks)*

A. In this unit, students learn of the changes in energy that accompany interactions between substances. They begin by asking questions about the source of energy in the chemical reaction that occurs when a sparkler is lighted. They analyze changes in energy during chemical reactions and use different types of models to describe the changes that occur. After predicting why changing the temperature of a light stick would affect the intensity of the light it emits, they gather evidence to explain the rates of reactions and the mechanisms by which the reactions occur.
- The learning experiences in this unit prepare students for mastery of the following performance expectations:

  - HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
  - HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
  - HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
  - HS-PS3-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
- The learning experiences in this unit prepare students for mastery of the following Environmental Principles and Concepts:
  - Principle 2: People Influence Natural Systems
  - Principle 4: There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing Between Systems

B. Lessons

- Lesson 1 – In this lesson, students use models in the form of chemical equations and graphs to explain changes of energy and matter that occur due to rearrangements of atoms during endothermic and exothermic reactions **(DCI PS1.B, CCC Stability and Change)**. They also use models to describe how changes of energy and matte in chemical reactions can produce stable molecules **(DCI PS1.A)**. Students then consider how the sum of all bond energies relates to changes in energy and matter during endothermic and exothermic reactions **(SEP Using Mathematical and Computational Thinking, DCI PS1.A)**.
- Lesson 2 – In this lesson, students plan and carry out an investigation to observe how changing reactant type, concentration, surface area, and temperature influence the rate of reaction **(SEP Planning and Carrying Out Investigations, DCI PS1.B)**. They construct explanations relating to reaction processes and reaction rates using collision theory and the kinetic energy of particles and apply what they learn to explain why glow sticks emit more light at warmer temperatures **(SEP Constructing Explanations and Designing Solutions, DCI PS1.B, CCC Energy and Matter, CCC Stability and Change)**. Students use graphs to model energy changes during a chemical reaction and analyze these graphs to determine the activation energy required to initiate a chemical reaction and the energy absorbed or released in the process **(DCI PS1.B, CCC Energy and Matter)**. Students learn how catalysts increase the rate of a reaction by lowering the activation energy required. Using concentration and reaction rate data, students determine the rate law equation for various reactions **(SEP Using Mathematic and Computation Thinking)** and compare patterns of change in first-order and second-order reactions **(CCC Patterns)**.

Unit 6: **Human Activity and Earth's Atmosphere** (*5 weeks)*

A. In this unit, students evaluate the benefits and costs of nonrenewable and renewable energy sources, including the impacts that energy extraction, transportations, and use have on the environment and human health. They will analyze data and develop models for energy flows and feedback in Earth's atmosphere, analyze human impacts on the Earth system, and evaluate possible solutions that involve acid-base chemistry.
   - The learning experiences in this unit prepare students for mastery of the following performance expectations:
     - HS-ESS2-2: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.
     - HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
     - HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*
     - HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
     - HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
     - HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
   - The learning experiences in this unit prepare students for mastery of the following Environmental Principle's and Concepts:
     - Principle 3: Natural Systems Change in Ways that People Benefit From and Can Influence
     - Principle 4: There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing Between Systems
     - Principle 5: Decisions Affecting Resources and Natural Systems are Complex and Involve Many Factors

B. Lessons
   - Lesson 1 – In this lesson, students will analyze data about human energy consumption and the environmental impacts related to energy provision and energy use **(SEP Analyzing and Interpreting Data, DCI ESS3.C, CCC Cause and Effect, CCC Patterns)**. Students will compare tradeoffs associated with different energy sources **(DCI ETS1.B)** and discuss energy transformations that take place as primary sources of energy are converted into the electrical energy that powers devices **(CCC Matter and Energy)**. Students will distinguish between renewable and nonrenewable energy sources. They will also calculate efficiency for different energy systems **(SEP Using Mathematics and Computational Thinking)** and identify ways in which humans can reduce their energy use or increase the efficiency of technologies that provide or use energy **(DCI ETS1.B)**. Students will

use a model to investigate the relationship between carbon dioxide and temperature in the atmosphere **(SEP Developing and Using Models)** and learn how the state of California has taken steps to reduce vehicle emissions.

- Lesson 2 – In this lesson, students develop and use models that show how the relationship between energy and matter applies to Earth's energy budget **(SEP Developing and Using Models, CCC Energy and Matter)**. They consider effects on weather and climate **(DCI ESS2.D, CCC Cause and Effect)**. Students analyze and interpret data **(SEP Analyzing and Interpreting Data**) to explore changes in Earth's precipitation and temperature **(DCI ESS2.D)**. They consider how various feedback systems are related to weather and climate **(DCI ESS2.A)**.
- Lesson 3 – In this lesson, students will compare the properties of acids and bases **(DCI PS1.B)** and they will analyze data to classify different household substances as acidic or basic **(SEP Analyzing and Interpreting Data)**. They will use mathematics to calculate pH, and they will learn that whole-number changes in pH indicate an exponential change in the concentration of hydronium ions in solution **(SEP Using Mathematics and Computational Thinking, CCC Scale, Proportion, and Quantity)**. Students will identify how human activities release acidic and basic chemicals that cause environmental problems, such as acid precipitation **(DCI ESS2.C, CCC Cause and Effect, CCC Systems and System Models)**. Students will evaluate advantages and tradeoffs related to different solutions for acid precipitation, including technologies that remove it from industrial wastes **(SEP Constructing Explanations and Designing Solutions, DCI ETS1.B, DCI ESS3.C)**.

Unit 7: **<u>Chemical Equilibrium Systems</u>** (*6 weeks)*

A. In this unit, students will study similar types of feedback in chemical systems in a state of dynamic equilibrium. They begin by analyzing data for chemical reactions and developing a model of chemical equilibrium. They investigate chemical systems and construct explanations for how these systems go through cycles of stability and change. They learn how a change in conditions affects a system at equilibrium. They investigate and develop engineering solutions to environmental problems related to ocean acidification and global pollution.
   - The learning experiences in this unit prepare students for mastery of the following performance expectations:
     - HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
     - HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*
     - HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

    - HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
- The learning experiences in this unit prepare students for mastery of the following Environmental Principles and Concepts:
    - Principle 3: Natural Systems Change in Ways that People Benefit From and Can Influence
    - Principle 4: There are no Permanent or Impermeable Boundaries that Prevent Matter from Flowing Between Systems

B. Lessons

- Lesson 1 – In this lesson, students will analyze data to develop a model of chemical equilibrium. They will study the concept of equilibrium as a dynamic balance between a forward reaction and a reverse reaction **(DCI PS1.B)** while constructing an explanation of what stays the same and what changes at equilibrium **(SEP Constructing Explanations and Designing Solutions, CCC Stability and Change)**.
- Lesson 2 – In this lesson, students will investigate chemical systems and construct explanations for how these systems go through cycles of stability and change **(SEP Constructing Explanations, DCI PS1.B, CCC Stability and Change)**. Students will explore how equilibrium systems of acids and bases change and how they remain stable to build an understanding of the dynamic and condition-dependent balance between a forward reaction and the reverse reaction **(DCI PS1.B, CCC Stability and Change)**. Students will use that understanding to construct explanations for how acid-base indicators function and how pH affects the ability of plants to grow in soil **(SEP Constructing Explanations)**. Then, students will explore how the solubility product affects the behavior of an acid-base system, as applied to the dynamic and condition-dependent balance between a forward reaction and the reverse reaction **(DCI PS1.B, CCC Stability and Change)**. Students use that understanding to construct explanations and refine solutions to real-world problems related to water quality **(SEP Constructing Explanations)**.
- Lesson 3 – In this lesson, students will model pH changes in seawater to construct explanations of how these changes cause real-world problems. They explore how new technologies affect society and determine how scientists and engineers refine solutions to a complex problem using criteria and tradeoffs **(SEP Constructing Explanations and Designing Solutions)**, the Haber-Bosch process serving as an example. Their explanation will consider lab observations regarding the balance between the forward and reverse reactions of the carbon dioxide-carbonate system in seawater **(DCI PS1.B)**. Students use data and observations to construct explanation about stability of equilibrium systems **(CCC Stability and Change)** and about how the balance between a forward reaction and its reverse reaction determines the balance of molecules in the system **(DCI PS1.B)**. They apply the concept of equilibrium as a solution to a real-world problem and develop criteria

(SEP Constructing Explanations and Designing Solutions) for a project to balance acidity in the ocean.

- Lesson 4 – Students learn how computer simulations and other studies lead to important discoveries about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities **(DCI ESS3.D)**. They investigate how diverse methods and procedures are used to obtain data about the effects of new technologies and their impacts on society and the environment. Students learn that analysis of costs and benefits is a critical aspect of decisions about technology and that computer modeling and other new technologies can be used to advance scientific knowledge. By studying global solutions and how they are implemented, students learn that in solutions, it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural and environmental impacts **(DCI ETS1.B)**. Through investigation of their proposed solutions, students confirm that science knowledge is based on empirical evidence obtained by analysis and modeling of system inputs and outputs **(CCC Systems and System Models)**.