AFK12SE Strand **DCI**	**Conceptual Understandings** **for Teachers at 9-12**
ESS1: Earth's Place in the Universe ***What is the universe, and what is Earth's place in it?***	
ESS1.A: The Universe and its stars *What is the Universe and what goes on in Stars?* ● The star called the Sun is changing and will burn out over 10 billion years. ● The Sun is just one of more than 200 billion stars in the Milky Way galaxy, and the Milky way is just one of hundreds of billions of galaxies in the Universe. ● The study of star's light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.	● How can the position and motion of the Sun, planets, and stars be observed, described, predicted, and explained with models? ● What evidence is used to support the current model for the formation and expansion of the universe? ● What nuclear reactions take place that result in the Sun radiating energy? ● How will the nuclear reactions in the Sun change over time? ● What do the spectra of distant stars reveal about their age and history? ● How do the spectra of stars and galaxies provide evidence of their chemical composition? ● What is the relationship between velocity and relative distance from Earth for these spectra?
ESS1.B: Earth and the Solar System *What are the predictable patterns caused by Earth's motion in the Solar System?* ● Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. ● Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, both occurring over tens to hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on Earth. These phenomena cause cycles of ice ages and other gradual climate changes.	● What types of objects can be found in the Solar System? ● How does gravity affect the motion of objects around the sun and/or around planets? ● What causes seasonal change on Earth? ● How can the mathematical representations of Kepler's Laws provide predictions of natural and man-made objects in the solar system? ● What is the nature and period of oscillations in Earth's motions? ● What positive and negative feedback can be seen in these oscillations?
ESS1.C: History of Planet Earth *How do people reconstruct and date events in Earth's planetary history?* ● Radioactive decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time.	● What evidence is collected and how is it interpreted to reconstruct Earth's history? ● What are the limitations of analyzing rock strata and the fossil record in reconstructing Earth's history? ● In what ways can the decay of radioactive isotopes be used to establish an absolute age for Earth materials?

● 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. ● Although active geological processes, such as plate tectonics, and erosion, have destroyed or altered most of the very early rock record 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 an provide information about Earth's formation and early history	● How do tectonic processes affect current patterns of continental and ocean floor features? ● How do the mineralogic and chemical compositions of Earth and solar system materials inform about the conditions of Earth's earliest history? ● How does the record of impacts and collisions provide information on the history of the Solar System?
ESS2: Earth's Systems ***How and why is Earth constantly changing?***	
ESS2.A: Earth Materials and Systems *How do Earth's major systems interact?* ● Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. 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 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 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 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.	● How do Earth's major systems interact to impact Earth processes? ● What spatial and temporal scales must be employed to observe changes and interactions in Earth's systems? ● In what ways can Earth's dynamic systems be modeled, over both short and long time spans? ● How does Earth's internal energy drive small- and large-scale crustal processes? ● How is the rate of change in Earth processes interrelated? ● How can seismic wave data indicate differences in density in the crust and mantle of the Earth? ● What causes motion in the Earth's mantle? ● How can the sequence of rocks in a given area provide evidence of the plate tectonic environment of their formation?

ESS2.B: Plate Tectonics and Large-Scale System Interactions *Why do the continents move, and what causes earthquakes and volcanoes?* ● The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle providing the primary source of the heat that drives mantle convection. ● Plate tectonics can be viewed as the surface expression of mantle convection.	● How does Plate Tectonic theory provide explanatory and predictive power for describing the evolution of Earth's surface? ● How does Plate Tectonics explain the distribution of rocks and minerals at Earth's surface? ● What map-pattern evidence can be employed to make retrodictions of the previous positions of Earth's plates? ● What are the sources of energy that drive Earth's surface and subsurface processes?
ESS2.C: The Roles of Water in Earth's Surface Processes *How do the properties and movements of water shape Earth's surface and affect its systems?* ● 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.	● How do the chemical and physical properties of water and its movement create changes in the surface and subsurface of the Earth? ● How does water mediate and facilitate short- and long-term Earth processes in the surface and subsurface?
ESS2.D: Weather and Climate *What regulates weather and climate?* ● 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 re-radiation into space. ● 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. ● Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	● How can data and models be used to extrapolate weather and climate patterns? ● What is the difference between weather and climate? ● What regulates weather and climate? ● What energy transformations occur to incoming solar radiation as it is transferred between Earth systems? ● What is the evidence in the rock and sediment record for changes in climate? ● What are drivers for climate change? ● Based on current rates of change in energy levels, what are some valid extrapolations for changes in climate and the impact on the biosphere, hydrosphere, and lithosphere?

ESS2.E: Biogeology *How do living organisms alter Earth's processes and structures?* ● The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.	● How have organisms on Earth evolved in response to changes in the Earth's major systems? ● How can organisms impact Earth's major systems? ● How would the Earth's lithosphere, atmosphere, and hydrosphere be different in the absence of life?
ESS3: Earth and Human Activity ***How do Earth's surface processes and human activities affect each other?***	
ESS3.A: Natural Resources *How do humans depend on Earth's resources?* ● 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.	● How do humans depend on Earth's resources? ● What has caused Earth's resources to be unevenly distributed? ● How has technology been employed to develop and exploit renewable energy resources? ● How can non-renewable resources be responsibly managed to sustain human use?
ESS3.B: Natural Hazards *How do natural hazards affect individuals and societies?* ● Natural hazards and other geological events have shaped the course of human history by destroying buildings and cities, eroding land, changing the course of rivers, and reducing the amount of arable land. These events have significantly altered the sizes of human populations and have driven human migrations. ● 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.	● What tools and models can be employed to make reliable predictions about the timing and intensity of natural hazards? ● How can we use information about past natural hazards to assist in forecasting future hazards? ● How have occurrences of natural hazards in local and regional environments driven human movements and populations in those environments?
ESS3.C: Human Impacts on Earth Systems *How do humans change the planet?* ● The sustainability of human societies and the biodiversity that supports them requires responsible management of natural	● How have organisms responded to changes in their environment as a result of human activity? ● What changes in human behavior and technology can mitigate the

resources. Scientists and engineers can make major contributions—for example, by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. ● When the source of an environmental problem is understood and international agreement can be reached, human activities can be regulated to mitigate global impacts (e.g., acid rain and the ozone hole near Antarctica).	negative impacts humans have had on Earth systems? ● What is the impact of different resource management approaches on natural resources long-term availability to people?
ESS3.D: Global Climate Change *How do people model and predict the effects of human activities on Earth's climate?* ● 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. ● 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 impacts. ● 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. Thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences—for humanity as well as for the rest of the planet.	● What human activities have positively impacted Earth's climate? ● What human activities have negatively impacted Earth's climate? ● How can knowledge from STEM areas and social science disciplines be used to mitigate the impact of humans on the Earth's climate? ● What technological resources are available to advance positive feedback and mitigate negative feedback caused by resource use by people?
Supporting Competencies	
Math	● How are statistics used by scientists to support arguments? ● How are mathematical models used in earth and space science?
Chemistry	● What is matter? ● What trends exist in the Periodic Table and how do those trends reflect atomic structure? ● In what ways do atoms combine to form novel substances? ● What conventions do chemists use for naming chemical compounds and writing chemical formulas? ● How does a balanced chemical reaction represent conservation of mass

	in a given chemical reaction? ● How does the amount of radioactive materials change over the course of a nuclear decay reaction?
Biology	● What are major organelles, and how do these impact cell function? ● How do organisms obtain and use the matter and energy they need to live and grow? ● What are the structural relationships among DNA, proteins, and genes? ● How do matter and energy move through an ecosystem? ● How does the environment influence populations of organisms over multiple generations? ● How do organisms grow and develop?
Physics	● What is energy and how is it measured? ● How is energy transferred between objects? ● What are the conceptual and mathematical relationships among energy, work, and power? ● What is meant by conservation of energy and conservation of mass? ● What is the relationship between thermal energy and temperature?