Developing and Using Science and Engineering Practices (by Lesson)

SEP Element #	Lesson	Elements of Science and Engineering Practice(s)	Rationale
1.1	1	Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.	Students ask questions that arise from their careful observations of a StoryMap and data to clarify and seek additional information about a crack in the Afar region of Ethiopia.
1.1	9	Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.	Students ask questions that arise from their careful observation of data about the ages of crustal rocks, to clarify and/or seek additional information about plate tectonics and the history and future of the Afar region.
1.2	3	Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.	Students ask questions arising from the development of the M-E-F model to clarify (1) additional relationships related to energy transfer and storage in deformed matter and (2) the model's application to various dynamics and interactions occurring in Earth systems at two points in the lesson: when they complete Question 4 on the handout and when they add new questions to their sticky note(s) for the exit ticket/home learning.
1.2	7	Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.	Students ask questions in the exit ticket at the end of day 1 that arise from examining models for explaining radioactive decay, to clarify and seek additional information regarding the relationships between matter, energy, and forces.
1.2	9	Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.	Students develop a model based on their observations and ask questions that arise from examining that model to clarify and/or seek additional information and relationships about plate tectonics and the history and future of the Afar region.
2.1	4	Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.	Students use these portions of this element: "Evaluate merits and limitations of two different models of the same ~~proposed tool,~~ process, mechanism ~~or system~~ in order to select ~~or revise a model that best fits the evidence or~~ design criteria." They do this on day 1 when they complete the [material:PF.L4.HO1] handout.
2.3	1	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.	Students develop a model that predicts relationships between parts of Earth to explain how processes underground can cause motion and cracking on the surface.
2.3	4	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.	Students use a particle-level simulation to explore cause-and-effect relationships between the magnitude of external forces acting on a solid, the changes in matter across different scales, and the energy changes in the system.

SEP Element #	Lesson	Elements of Science and Engineering Practice(s)	Rationale
2.3	6	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.	Students develop an individual model based upon evidence of the heterogeneity of the mantle from tomography data to predict the relationship between temperature and density differences of parcels in the mantle and their movement within the mantle system. They then revise the model as a class to include particle-level matter changes and force interactions between sections of matter within the mantle tank based upon the energy transferring into the system and how that energy affects the behavior of matter. They explain thermal convection in the mantle from a matter, energy, and forces perspective.
2.3	11	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.	Students develop an initial model of the effects of multiple forces acting on the plate systems at the same time. They then revise their model to predict what would happen to those forces if one of the physical properties of a plate is increased or decreased (relationship between the components of the system). Students engage in an investigation and revise their models to show the relationship between mass, surface area, or texture and the force of friction on plate movement.
2.3	12	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.	Students use quantitative force diagrams and the Pythagorean theorem to make sense of and illustrate the relationship between the force of gravity and motion of objects on varying inclines.
2.6	2	Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.	Students develop and use free-body diagrams (models) to predict changes in an object and the magnitude of the forces applied to it under different combinations of contact forces.
2.6	10	Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.	On day 1, students record observations about the surface features they observe in a computer simulation of convergent and divergent plate boundaries. On day 2, they use their findings, together with the consensus model and additional sources of evidence, to make predictions about the future of Afar, taking into consideration the limitations of and assumptions about the models.
3.2	2	Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, 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.	Students plan and conduct investigations collaboratively to produce data to serve as the basis for evidence about the contact force conditions that result in stability or changing motion in a system. They decide on types (adding or removing forces), how much (magnitude of forces and number of contact forces), and accuracy of data needed to produce reliable measurements.

SEP Element #	Lesson	Elements of Science and Engineering Practice(s)	Rationale
4.1	5	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.	Students analyze tomography data and topographic maps using the SubMachine digital tool to make claims about a causal link between heterogeneity in Earth's mantle and surface features.
4.1	8	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.	Students engage in this element when they use an exponential decay law to estimate the age of a different rock sample using the relationships they discovered from their prior investigations and use the patterns in the rocks to reconstruct the geologic history of Afar over the last 700 million years when they complete the handout.
4.5	5	Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.	Students evaluate the impact of new tomography data, obtained using a digital tool, on our working model of Earth's interior. They discuss in partners and as a class how to revise the model in light of this data to include regional heterogeneity in the mantle. They record their revised models in their Progress Trackers.
5.2	5	Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.	Students analyze empirical data to reveal an anomaly in the pattern of arrival times for seismic waves when the chord the waves follow through the globe is approximately 10,000 km or more. In the exit ticket on day 1, students use our working model of Earth's interior to make a claim about which layers P-waves and S-waves travel through, supporting their claim with evidence from mathematical representations.
5.2	8	Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.	Students engage in this element when they (a) sketch graphs of predicted relationships for percent of parent and daughter elements versus time and describe how those relationships would compare for different-sized crystals and different parent elements when they complete the handout, and (b) describe patterns in the graphs generated with the data they collected as a group when they complete the handout.
5.2	12	Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.	Students represent the forces on plates using quantitative force diagrams to explain how the force of gravity can pull an object down an incline and how the force component down the ramp varies with the angle of the incline.
6.1	3	Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.	Students use this element when they complete Questions 1 and 2 on the handout, making two qualitative claims about how differences in the magnitude of forces (cause) (1) acting on different materials would result in similar effects in their structure (elastic deformation) and (2) acting on a single material would affect the amount of energy transferred into and out of it.

SEP Element #	Lesson	Elements of Science and Engineering Practice(s)	Rationale
6.2	7	Construct and revise an explanation 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.	Students co-construct an explanation for how radioactive decay provides the heat that drives mantle convection, using ideas from our previous investigations, new evidence from a set of complementary readings, and the assumption that our past observations about the relationships between matter, forces, and energy hold true across contexts.
6.2	10	Construct and revise an explanation 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.	On day 2, students construct an explanation about the future of Afar based on a variety of sources and the assumption that plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. At the end of day 2, following the development of the consensus model, students revise their explanations.
6.2	13	Construct and revise an explanation 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.	Students revisit the Driving Question Board to answer questions about the process of plate tectonics both in the past and in the future. They consider past partial explanations and give evidence that was used to revise their explanations, as well as consider evidence to answer new questions.

Developing and Using Crosscutting Concepts (by Lesson)

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
1.1	5	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.	After problematizing the grain size at which our data describe the matter in Earth's layers, students make claims about a causal link between heterogeneity in Earth's mantle and surface features using additional data at a smaller, regional scale.
1.2	5	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.	Students problematize our working model of Earth's mantle as regionally homogeneous and seek additional data at a regional scale. They discuss in partners and as a class how to revise our model in light of this data to include regional heterogeneity in the mantle.
1.4	5	Mathematical representations are needed to identify some patterns.	On day 1, students use mathematical representations to identify anomalous patterns in seismic wave velocities. During navigation into day 2, they respond to a reflection question on how indirect empirical evidence and mathematical representations helped them identify patterns and anomalies in seismic velocities to support their reasoning.

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
1.4	8	Mathematical representations are needed to identify some patterns.	Students use the idea that mathematical representations (graphs) are needed to identify some patterns in the data, when they (a) sketch graphs of predicted relationships for parent and daughter elements force versus time, and (b) describe patterns in the related graphs, and (c) compare these to patterns predicted by an exponential decay law.
1.5	8	Empirical evidence is needed to identify patterns	Students use empirical evidence collected from crystal in rock samples collected in the Afar region to identify patterns that support interpretations about the geologic history of this area.
1.5	9	Empirical evidence is needed to identify patterns	Students use data about the ages of crustal rocks to identify patterns.
1.5	10	Empirical evidence is needed to identify patterns	During day 2, students use the simulation and the consensus model of plate interactions at plate boundaries to explain the patterns in the radiometric data explored in Lesson 9.
2.2	1	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.	Students suggest cause-and-effect relationships on Earth's surface by considering what happens beneath the surface and explicitly discussing the spatial and temporal scales at which these changes might be happening.
2.2	3	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.	Students use data from a reading to make qualitative claims about how differences in the magnitude of forces (cause) acting on different materials would result in similar effects in their structure (elastic deformation). This data includes ratios that reference the amount of deformation at a very small scale.
2.2	4	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.	Students explore cause-and-effect relationships between force, matter, and energy by examining the effects of external forces on particle-level interactions.
2.2	7	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.	Students use information about nuclear-scale mechanisms to suggest a series of cause-and-effect relationships that explain the complex phenomenon of mantle convection.
3.2	1	Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.	Students ask questions about geologic processes that are too large and too slow to observe directly.
3.2	4	Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.	Students use a computer simulation and a physical model (inverter magnets) to investigate the effect of external forces on matter and energy changes at the particle level.

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
3.2	5	Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.	On day 1, students consider connections across disciplines by discussing other systems we have learned about that cannot be studied directly because they are too small, too large, too fast, or too slow. They do this in pairs and then discuss as a class.
3.2	11	Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.	Students develop models of forces acting on components of the crust and mantle system that are too slow and large to be observed directly. The process of plate movement occurs at such a slow rate that it is hard to observe directly, and observable movement generally occurs over large periods of time. Similarly, the spatial scale of a plate is too large to study directly, and the forces acting on the plate cannot be studied directly on that scale.
3.2	12	Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.	Students use bottles on ramps to study and make sense of the force of gravity acting on the parts of plates, and discuss the use of a model system that is small enough and can change motion within observable timescales, because actual plate forces and motion are too slow and large to observe directly.
3.3	1	Patterns observable at one scale may not be observable or exist at other scales.	Students consider and wonder about patterns they can only observe when zooming in and out on a map, revealing patterns that exist only at certain scales.
3.3	7	Patterns observable at one scale may not be observable or exist at other scales.	Students use the concept of strong forces that only exist at the nuclear scale to explain patterns of mantle convection at the global scale.
4.2	2	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.	Students use subsystem thinking, which focuses on force interactions on a single object among multiple objects within a larger system, when they use free-body diagrams as a tool to isolate a single part from a larger system and consider only the force interactions acting upon that part from the other parts.
4.3	10	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.	During day 1, students use a computer model to simulate the interactions between plates at different boundaries. This simulation helps them notice the flow of magma between the mantle and the plates, leading to formation of new crustal rocks, which motivates a closer look at the flow of matter in this system.
4.4	10	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	During day 2, students use the consensus model and multiple sources of evidence gathered throughout the unit to predict the behavior of Afar. They use evidence to explain their predictions.

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
5.2	3	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.	Students use this element in the whole-class discussion of the results from deforming the foam panel, in the claim they write in response to Question 2 on the handout, and in the questions they raise about what is happening in Earth systems.
5.4	6	Energy drives the cycling of matter within and between systems.	Students analyze video data of a fish tank of matter representing the mantle. Heat is applied to the mantle tank in the video. Students use what they see happening with energy and matter in this investigation to develop a convection model of the matter in the mantle.
6.2	3	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	Students use this portion of this element in this lesson: *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~~*. They use this when they cite examples of other materials that exhibit elastic behavior, when they make an initial claim about whether rock would as well, and in the claim they write in response to Question 1 on the handout.
7.1	2	Much of science deals with constructing explanations of how things change and how they remain stable.	Students are introduced to (and use) the ideas that (1) all phenomena in science can be considered either stable or changing, depending on the scale at which they are studied, and that (2) much of science deals with constructing explanations of how things change and how they remain stable, and (3) determining the appropriate scale(s) to study a phenomenon can help us explain *why* it happened. Students also reflect on whether (and how) using thinking about stability or change over time helped them figure something out in their Progress Tracker, although this is not used as a formative assessment. The same self-reflection prompts related to the use of this crosscutting concept will recur over the course of the unit, each time a new tracker entry is made.

CCC Elements #	Lesson	Elements of Crosscutting Concept(s)	Rationale
7.1	3	Much of science deals with constructing explanations of how things change and how they remain stable.	Students use this element when they develop the M-E-F poster and the description of the foam panel system on the board as a class, for the corresponding three stable states and two intermediate state changes. In this development, they reuse the idea from Lesson 2 that balanced versus unbalanced forces explain stability and change in matter. A prior unit developed the idea that changes in matter and transfers of energy happen together (correlation). In this lesson, students develop the idea that forces are a causal mechanism for changes in matter, and therefore could also be a causal mechanism for energy transfer. Students also use GPS motion data at Earth's surface to make claims in their response to Question 3 on the handout about what matter change they expect in a rock that was stable before it was extracted from plate material in the Afar region.
7.1	4	Much of science deals with constructing explanations of how things change and how they remain stable.	Students use two physical models (foam and inverter magnets) and one simulation to show how unbalanced forces and energy transfers can explain why solids elastically deform (change) up to a point (stability), and what happens to it when it breaks.
7.2	13	Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.	Students revisit the Driving Question Board and answer their questions. As they do so, they consider the scale of the change (spatial and temporal) in their answers, and how the related process might cause other changes over time.

Disciplinary Core Ideas (by Lesson)

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
ESS2.A.1	2	Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HSESS2-1),(HS-ESS2-2)	Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-1, HS-ESS2-2)
ESS2.A.1	3	Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HSESS2-1),(HS-ESS2-2)	Earth's systems, being dynamic and interacting, cause ~~feedback~~ effects that can increase or decrease the original changes.
PS4.A.1	5	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. (HS-PS4-1)	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. (HS-PS4-1)
PS1.C.1	7	Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HSPS1-8)	Nuclear processes, including ~~fusion, fission, and~~ radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change ~~in any nuclear process~~. (HS-PS1-8)

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
ESS2.B.1	7	The radioactive decay of unstable isotopes continually generatesnew 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. (HS-ESS2-3)	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.~~ (HS-ESS2-3)
ESS1.C.1	9	Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (HS-ESS1-5)	Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. (HS-ESS1-5)
ESS2.B.1	10	The radioactive decay of unstable isotopes continually generatesnew 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. (HS-ESS2-3)	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. (HS-ESS2-3)
PS3.B.2	3	Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4)	Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
PS3.B.2	4	Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4)	Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1, HS-PS3-4)
ESS2.B.2	4	Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (HS-ESS2-1) (secondary to HS-ESS1-5)	Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE), (HS-ESS2-1, secondary to HS-ESS1-5)
ESS2.A.2	5	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. 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 gravitational movement of denser materials toward the interior. (HS-ESS2-3)	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. ~~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 gravitational movement of denser materials toward the interior.~~ (HS-ESS2-3)
ESS2.A.2	6	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. 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 gravitational movement of denser materials toward the interior. (HS-ESS2-3)	~~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.~~ 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 gravitational movement of denser materials toward the interior. (HS-ESS2-3)

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
PS2.B.2	7	Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5)	Forces at a distance are explained by fields (~~gravitational,~~ electric~~, and magnetic~~) permeating space that can transfer energy through space. ~~Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.~~ (HS-PS2-4, HS-PS2-5)
PS3.A.2	7	At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2) (HS-PS3-3)	At the macroscopic scale, energy manifests itself in multiple ways, such as in motion~~;~~ ~~sound, light,~~ and thermal energy. (HS-PS3-2, HS-PS3-3)
PS1.C.2	8	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. (secondary to HS-ESS1-5), (secondary to HS-ESS1-6)	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. (secondary to HS-ESS1-5, secondary to HS-ESS1-6)
ESS2.B.2	10	Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (HS-ESS2-1) (secondary to HS-ESS1-5)	Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (HS-ESS2-1) (secondary to HS-ESS1-5)
ESS2.A.2	11	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. 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 gravitational movement of denser materials toward the interior. (HS-ESS2-3)	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 ~~gravitational~~ movement of ~~denser~~ materials toward the interior~~.~~ (HS-ESS2-3)
ESS2.A.2	12	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. 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 gravitational movement of denser materials toward the interior. (HS-ESS2-3)	**Earth Material and Systems.** 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. 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~~ gravitational movement of denser materials toward the interior. (HS-ESS2-3)

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
ESS2.A.2	13	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. 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 gravitational movement of denser materials toward the interior. (HS-ESS2-3)	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. 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 gravitational movement of denser materials toward the interior. (HS-ESS2-3)
ESS2.B.2	13	Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (HS-ESS2-1) (secondary to HS-ESS1-5)	Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. (ESS2.B Grade 8 GBE) (HS-ESS2-1) (secondary to HS-ESS1-5)
PS2.B.3	4	Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6), (secondary to HS-PS1-1),(secondary to HS-PS1-3)	Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter~~, as well as the contact forces between material objects~~. (HS-PS2-6, secondary to HS-PS1-1, secondary to HSPS1-3)
ESS2.B.3	10	Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (HS-ESS2-1)	Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (HS-ESS2-1)
ESS2.B.3	13	Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (HS-ESS2-1)	Plate movements are responsible for most ~~continental and~~ ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (HS-ESS2-1)
PS3.A.4	4	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). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)	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). ~~This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.~~ (HS-PS3-2)
PS4.A.4	5	Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (secondary to HS-ESS2-3)	Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (secondary to HS-ESS2-3)
PS3.A.4	6	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). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)	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). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space~~. (HS-PS3-2)

DCI Elements #	Lesson	Elements of Disciplinary Core Idea(s)	Rationale
PS3.A.4	7	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). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)	These relationships are better understood at the microscopic scale, at which all the different manifestations of energy can be modeled as either motions of particles or energy stored in fields (which mediate interactions between particles)~~. This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.~~ (HS-PS3-2)