NEXT GENERATION SCIENCE STANDARDS

The following documents show the May 2012 Draft NGSS performance expectations grouped by topics.

High School

May 7, 2012

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HS.LS-SFIP Structure, Function, and Information Processing

HS.LS-SFIP Structure, Function, and Information Processing

Students who demonstrate understanding can:

a. **Obtain and communicate information explaining how the structure and function of systems of specialized cells within organisms help them perform the essential functions of life.** [Assessment Boundary: Limited to conceptual understanding of chemical reactions that take place between different types of molecules such as water, carbohydrates, lipids, and nucleic acids.]

b. **Communicate information about how DNA sequences determine the structure and function of proteins.** [Assessment Boundary: Limited to conceptual understanding of how the sequence of nitrogen bases in DNA determine the amino acid sequence and the structure and function of the protein it codes for, not the actual protein structure.]

c. **Develop and use models to explain the hierarchical organization of interacting systems working together to provide specific functions within multicellular organisms.** [Clarification Statement: Levels of organization should include cells, tissues, organs, systems, and organisms.] [Assessment Boundary: The focus is on the basic organization of systems across several levels of organization.]

d. **Use modeling to explain the function of positive and negative feedback mechanisms in maintaining homeostasis that is essential for organisms.** [Assessment Boundary: The focus is on conceptual models explaining examples of both types of feedback systems.]

e. **Use evidence to support explanations for the relationship between a region of the brain and the primary function of that region.** [Clarification Statement: Conceptual understanding that the brain is divided into several distinct regions and circuits, each of which primarily serves dedicated functions (e.g., visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, decision making about actions to take in the event of certain inputs).]

f. **Gather and communicate information to explain the integrated functioning of all parts of the brain for successful interpretation of inputs and generation of behaviors.** [Assessment Boundary: Conceptual understanding is limited to the structure and function of the brains of complex organisms.]

g. **Analyze and interpret data to identify patterns of behavior that motivate organisms to seek rewards, avoid punishments, develop fears, or form attachments to members of their own species and, in some cases, to individuals of other species.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (c),(d)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (c),(d)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. (g)
- Evaluate the impact of new data on a working explanation of a phenomenon or design solution. (g)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (a),(b),(e),(f)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (a),(b),(e),(f)

Disciplinary Core Ideas

LS1.A: Structure and Function

- 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. (a)
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells. (b)
- 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. (c)
- 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 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. (d)

LS1.D: Information Processing

- In complex animals, the brain is divided into several distinct regions and circuits, each of which primarily serves dedicated functions, such as visual perception, auditory perception, interpretation of perceptual information, guidance of motor movement, and decision making about actions to take in the event of certain inputs. (e)
- In addition, some circuits give rise to emotions and memories that motivate organisms to seek rewards, avoid punishments, develop fears, or form attachments to members of their own species and, in some cases, to individuals of other species (e.g., mixed herds of mammals, mixed flocks of birds). (g)
- The integrated functioning of all parts of the brain is important for successful interpretation of inputs and generation of behaviors in response to them. (f)

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 identity some patterns. (g)

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. (f)

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. (c)

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. (a),(b),(e)

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. (d)

'S.LS-SFIP	**Structure, Function, and Information Processing**
ɔnnections to other topics in this grade-level: **HS.ESS-CC, HS.PS-CR, HS.PS-E, HS.ETS-ETSS**	
Articulation across grade-levels: **MS.LS-SFIP**	

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

SL.9-10.2 Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.

RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), nothing when the findings support or contradict previous explanations or accounts.

SL.11-12.2 Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Mathematics –

S.ID Summarize, represent, and interpret data on two categorical and quantitative variables

S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.LS-MEOE Matter and Energy in Organisms and Ecosystems

LS-MEOE Matter and Energy in Organisms and Ecosystems

Students who demonstrate understanding can:

a. **Construct a model to support explanations of the process of photosynthesis by which light energy is converted to stored chemical energy.** [Clarification Statement: Models may include diagrams and chemical equations. The focus should be on the flow of matter and energy through plants.] [Assessment Boundary: Limited to the inputs and outputs of photosynthesis and chemosynthesis, not the specific biochemical steps involved.]

b. **Construct an explanation of how sugar molecules that contain carbon, hydrogen, and oxygen are combined with other elements to form amino acids and other large carbon-based molecules.** [Clarification Statement: Explanations should include descriptions of how the cycling of these elements provide evidence of matter conservation.] [Assessment Boundary: Focus is on conceptual understanding of the cycling of matter and the basic building blocks of organic compounds, not the actual process.]

c. **Use a model to explain cellular respiration as a chemical process whereby the bonds of food molecules and oxygen molecules are broken and bonds in new compounds are formed that result in a net transfer of energy.** [Assessment Boundary: Limited to the conceptual understanding of the inputs and outputs of metabolism, not the specific steps.]

d. **Evaluate data to compare the energy efficiency of aerobic and anaerobic respiration within organisms.** [Assessment Boundary: Limited to a comparison of ATP input and output.]

e. **Use data to develop mathematical models to describe the flow of matter and energy between organisms and the ecosystem.** [Assessment Boundary: Use data on energy stored in biomass that is transferred from one trophic level to another.]

f. **Communicate descriptions of the roles of photosynthesis and cellular respiration in the carbon cycle specific to the carbon exchanges among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.**

g. **Provide evidence to support explanations of how elements and energy are conserved as they cycle through ecosystems and how organisms compete for matter and energy.** [Clarification Statement: Elements included can include carbon, oxygen, hydrogen, and nitrogen.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (a),(c),(e)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (a),(c)
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (e)
- Examine merits and limitations of various models in order to select or revise a model that best fits the evidence or the design criteria. (a),(c)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative claims regarding the relationship between dependent and independent variables. (g)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (g)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (b),(g)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (f)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (f)

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in 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: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. (a),(b),(g)
- As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. (b),(c)
- As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. For example, aerobic (in the presence of oxygen) cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. (c),(d)
- Anaerobic (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. (d)
- Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy loss to the surrounding environment. (c)
- Matter and energy are conserved in each change. This is true of all biological systems, from individual cells to ecosystems. (g)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (c),(e)
- 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. (e)
- The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; (g)
- Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. (b),(e)
- Competition among species is ultimately competition for the matter and energy needed for life. (g)
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged between the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. (f)

Crosscutting Concepts

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. (f),(g)

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—it 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. (a),(b),(c),(d),(e)

HS.LS-MEOE Matter and Energy in Organisms and Ecosystems

'S.LS-MEOE Matter and Energy in Organisms and Ecosystems *(continued)*

onnections to other topics in this grave-level: **HS.ESS-HS, HS.PS-CR, HS.PS-E, HS.PS-SPM**

Articulation across grade-levels: **MS.LS-MEOE, MS.LS-IRE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RI.9-10.1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

RI.9-10-8 Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient identify false statements and fallacious reasoning.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with Mathematics.

MP.5 Use appropriate tools strategically.

S.ID Summarize, represent, and interpret data on a single count or measurement variable.

F.BF Build a function that models a relationship between two quantities.

N-Q Reason quantitatively and use units to solve problems.

HS.LS-IRE Interdependent Relationships in Ecosystems

LS-IRE Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

a. **Evaluate data to explain resource availability and other environmental factors that affect carrying capacity of ecosystems.** [Clarification Statement: The explanation could be based on computational or mathematical models. Environmental factors should include availability of living and nonliving resources and from challenges (e.g., predation, competition, disease).]

b. **Design solutions for creating or maintaining the sustainability of local ecosystems.**

c. **Construct and use a model to communicate how complex sets of interactions in ecosystems maintain relatively consistent numbers and types of organisms for long periods of time when conditions are stable.**

d. **Construct arguments from evidence about the effects of natural biological or physical disturbances in terms of the time needed to reestablish a stable ecosystem and how the new system differs from the original system.** [Clarification Statement: Computational models could be used to support collect evidence to support the argument.]

e. **Use evidence to construct explanations and design solutions for the impact of human activities on the environment and ways to sustain biodiversity and maintain the planet's natural capital.** [Clarification Statement: Explanations and solutions should include anthropogenic changes (e.g., habitat destruction, pollution, introduction of invasive species, overexploitation, climate change).]

f. **Argue from evidence obtained from scientific literature the role group behavior has in increasing the chances of survival for individuals and their genetic relatives.**

g. **Plan and carry out investigations to make mathematical comparisons of the populations and biodiversities of two similar ecosystems at different scales.** [Clarification Statement: Students compare, mathematically, the biodiversity of a small ecosystem to a large ecosystem (e.g., woodlot to a forest, small pond near a city to a wetland estuary).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 9-12 builds on K-8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.
- Construct, revise, and use models to predict and explain relationships between systems and their components. (c)
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (c)

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.
- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects and ensure the investigation's design has controlled for them. (g)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.
- Make quantitative claims regarding the relationship between dependent and independent variables. (b),(e)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (e)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e)
- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (b),(e)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9-12 builds from K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.
- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of arguments. (d),(f)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 9-12 builds on 6-8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.
- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (a)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (a)

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems
- 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 nonliving resources and from such challenges such 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. (a),(g)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- 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. (c)
- 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. (d)
- Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. (a),(d)
- 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. (e)

LS2.D: Social Interactions and Group Behavior
- Animals, including humans, having a strong drive for social affiliation with members of their own species and will suffer, behaviorally as well as physiologically, if reared in isolation, even if all their physical needs are met. Some forms of affiliation arise from the bonds between offspring and parents. Other groups form among peers. Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. (f)

LS4.D: Biodiversity and Humans
- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital. (d),(e)
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse 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. (b),(e)

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. (a),(f)

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. (g)

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. (b),(c),(d),(e)

HS.LS-IRE Interdependent Relationships in Ecosystems

.LS-IRE Interdependent Relationships in Ecosystems *(continued)*	
Connections to other topics in this grade-level: **HS.ESS-HE, HS.ESS-ES, HS.ESS-HS**	
Articulation across grade-levels: **MS.LS-IRE, MS.LS-NSA, MS.LS-MEOE**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
RI.9-10.1	Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.
RI.9-10-8	Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient identify false statements and fallacious reasoning.
W.9-10.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
W.11-12.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
RST.9-10.10	By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.
Mathematics –	
MP.1	Make sense of problems and persevere in solving them.
MP.3	Construct viable arguments and critique the reasoning of others.
N-Q	Reason quantitatively and use units to solve problems.

HS.LS-NSE Natural Selection and Evolution

LS-NSE Natural Selection and Evolution

Students who demonstrate understanding can:

a. **Use models to explain how the process of 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 limited resources, and (4) the selection of those organisms that are better able to survive and reproduce in the environment.** [Clarification Statement: Mathematical models may be used to communicate the explanation or to generate evidence supporting the explanation.]

b. **Use evidence to explain the process by which natural selection leads to adaptations that result in populations dominated by organisms that are anatomically, behaviorally, and physiologically able to survive and/or reproduce in a specific environment.** [Assessment Boundary: Evidence should center on survival advantages of selected traits for different environmental changes such as temperature, climate, acidity, light.]

c. **Analyze and interpret data to explain the process by which organisms with an advantageous heritable trait tend to increase in numbers in future generations; but organisms that lack an advantageous heritable trait tend to decrease in numbers in future generations.**

d. **Obtain and communicate information describing how changes in environmental conditions can affect the distribution of traits in a population and cause increases in the numbers of some species, the emergence of new species, and the extinction of other species.**

e. **Use evidence obtained from new technologies to compare similarity in DNA sequences, anatomical structures, and embryological appearance as evidence to support multiple lines of descent in evolution.**

f. **Plan and carry out investigations to gather evidence of patterns in the relationship between natural selection and changes in the environment.** [Clarification Statement: A possible investigation could be to study fruit flies and the number of eggs, larvae, and flies that hatch in response to environmental changes such as temperature, moisture, and acidity.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (a)

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.

- Evaluate various methods of collecting data (e.g., field study, experimental design, simulations) and analyze components of the design in terms of various aspects of the study. Decide types, how much, and accuracy of data needed to produce reliable measurement and consider any limitations on the precision of the data (e.g., number of trials, cost, risk, time). (f)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (c)
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. (c)
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. (c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (b)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (b)
- Base casual 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. (b)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (d),(e)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (d),(e)

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- 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 descent 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. (e)

LS4.B: Natural Selection

- 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. (a),(c)
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (b),(c),(d),(f)

LS4.C: Adaptation

- 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. (a)
- 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. (b),(c),(f)
- Adaptation also means that the distribution of traits in a population can change when conditions change. (d)
- 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. (d)
- 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 drastic, the opportunity for the species' evolution is lost. (d)

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. (c),(e),(f)

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. (a),(b),(d)

ıS.LS-NSE **Natural Selection and Evolution** ***(continued)***
Connections to other topics in this grade-level: **HS.ESS-HE, HS.ESS-CC**
Articulation across grade-levels: **MS.LS-NSA, MS.LS-GDRO**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.9-10.1** Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text. **RI.9-10-8** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient identify false statements and fallacious reasoning. **SL.9-10.2** Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. **SL.11-12.2** Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. *Mathematics –* **MP.3** Construct viable arguments and critique the reasoning of others. **N-Q** Reason quantitatively and use units to solve problems **S.ID** Summarize, represent, and interpret data on a single count or measurement variable **S.IC** Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.LS-IVT Inheritance and Variation of Traits

S-IVT Inheritance and Variation of Traits

Students who demonstrate understanding can:

a. Ask questions and obtain information about the role of patterns of gene sequences in DNA molecules and subsequent inheritance of traits.

b. Use a model to explain how mitotic cell division results in daughter cells with identical patterns of genetic materials essential for growth and repair of multicellular organisms. [Assessment Boundary: The focus is on conceptual understanding of the process; the details of the individual steps are beyond the intent.]

c. Construct an explanation for how cell differentiation is the result of activation or inactivation of specific genes as well as small differences in the immediate environment of the cells. [Assessment Boundary: Limited to the concept that a single cell develops into a variety of differentiated cells and thus, a complex organism.]

d. Use a model to describe the role of cellular division and differentiation to produce and maintain complex organisms composed of organ systems and tissue subsystems that work together to meet the needs of the entire organism. [Clarification Statement: The focus is on the conceptual understanding that a single cell can give rise to complex, multicellular organisms consisting of many different cells with identical genetic material.] [Assessment Boundary: Limited to the concept that a single cell develops into a variety of differentiated cells and thus, a complex organism.]

e. Communicate information about the role of the structure of DNA and the mechanisms in meiosis for transmitting genetic information from parents to offspring. [Assessment Boundary: The focus is on conceptual understanding of the process; details of the individual steps of the process of meiosis are beyond the intent.]

f. Communicate information that inheritable genetic variations may result from: (1) genetic combinations in haploid sex cells, (2) errors occurring during replication, (3) crossover between homologous chromosomes during meiosis, and (4) environmental factors. [Clarification Statement: Information on genetic variation should include evidence of understanding the probability of variations and the rarity of mutations.] [Assessment Boundary: The focus is on conceptual understanding of the sources of genetic variation that are heritable.]

g. Use probability to explain the variation and distribution of expressed traits in a population. [Assessment Boundary: Hardy-Weinberg calculations are beyond the intent of this standard.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9-12 builds from grades K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.

- Ask questions that arise from phenomena, models, theory, or unexpected results. (a)
- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (a)

Developing and Using Models

Modeling in 9-12 builds on K-8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (b)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use statistical and mathematical techniques and structure data (e.g. displays, tables, graphs) to find regularities, patterns (e.g. fitting mathematical curves to data), and relationships in data. (g)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (c),(d)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, and theories) and peer review. (c),(d)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9-12 builds on 6-8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (f)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (e),(f)

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. (a),(b)
- As successive subdivisions of an embryo's cells occur, programmed genetic instructions and small differences in their immediate environments activate or inactivate different genes, which cause the cells to develop differently—a process called differentiation. 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. (b),(c),(d)
- In sexual reproduction, a specialized type of cell division called meiosis occurs that results in the production of sex cells, such as gametes in animals (sperm and eggs), which contain only one member from each chromosome pair in the parent cell. (e)

LS3.A: Inheritance of Traits

- In all organisms the genetic instructions for forming species' characteristics are carried in the chromosomes. (f)
- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. (a)
- All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (c),(f),(g)

LS3.B: Variation of Traits

- The information passed from parents to offspring is coded in the DNA molecules that form the chromosomes. (a)
- 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. (f)
- 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. (f)
- 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 depends on both genetic and environmental factors. (g)

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 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 identity some patterns. (a),(b)

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. (c),(f),(g)

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. (d)

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. (e)

LS-IVT Inheritance and Variation of Traits *(continued)*

…nections to other topics in this grade-level: **HS.LS-NSE**

Articulation across grade-levels: **MS.LS-GDRO**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

SL.1	Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
W.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
W.9	Draw evidence from literary or informational texts to support analysis, reflection, and research.
RST.9-10.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Mathematics –

MP.2	Reason abstractly and quantitatively.
F.BF	Build a function that models a relationship between two quantities.
A.CED	Create equations that describe numbers or relationships.
S.MD	Use probability to evaluate outcomes of decisions

HS.ESS-SS Space Systems

ESS-SS Space Systems

Students who demonstrate understanding can:

a. **Construct explanations from evidence about how the stability and structure of the sun change over its lifetime at time scales that are short (solar flares), medium (the hot spot cycle), and long (changes over its 10-billion-year lifetime).** [Clarification Statement: Evidence for long-term changes includes the Hertzsprung-Russell Diagram.]

b. **Use mathematical, graphical, or computational models to represent the distribution and patterns of galaxies and galaxy clusters in the Universe to describe the Sun's place in space.**

c. **Construct explanations for how the Big Bang theory accounts for all observable astronomical data including the red shift of starlight from galaxies, cosmic microwave background, and composition of stars and nonstellar gases.**

d. **Obtain, evaluate, and communicate information about the process by which stars produce all elements except those elements formed during the Big Bang.** [Clarification Statement: Nuclear fusion within certain stars produce atomic nuclei lighter than and including iron; heavier elements are produced when certain massive stars achieve a supernova stage and explode.]

e. **Use mathematical representations of the positions of objects in the Solar System to predict their motions and gravitational effects on each other.** [Assessment Boundary: Mathematical representations, which include Kepler's Laws, should not deal with more than 2 bodies.]

f. **Analyze evidence to show how changes in Earth's orbital parameters affect the intensity and distribution of sunlight on Earth's surface, causing cyclical climate changes that include past Ice Ages.** [Assessment Boundary: Orbital parameters are limited to change in orbital shape and orientation of the planetary axis.]

g. **Construct explanations for how differences in orbital parameters, combined with the object's size and composition, control the surface conditions of other planets and moons within the solar system.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (f)

Using Mathematical and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use statistical and mathematical techniques and structure data (e.g., displays, tables, graphs) to find regularities, patterns (e.g., fitting mathematical curves to data), and relationships in data. (b)
- Use simple limit cases to test mathematical expressions, computer programs or algorithms, or simulations to see if a model "makes sense" by comparing the outcomes with what is known about the real world. (e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

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

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (d)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. (a)
- The sun is 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. (b)
- The spectra and brightness of stars are used to identify their compositional elements, movements, and distances from Earth and to develop explanations about the formation, age, and composition of the universe. The Big Bang theory is supported by the fact that it provides an explanation of observations of distant galaxies receding from our own, of the measured composition of stars and nonstellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (c)
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (c),(d)

ESS1.B: Earth and the Solar System

- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (e)
- Cyclic changes in the shape of Earth's orbit around the sun, together with changes in the orientation of the planet's axis of rotation, have altered the intensity and distribution of sunlight falling on Earth. These changes, both occurring over tens to hundreds of thousands of years, cause cycles of ice ages and other gradual climate changes. (f),(g)

Crosscutting Concepts

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. (b)

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. (e),(g)

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—it 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. (a),(c),(d),(f)

HS.ESS-SS Space Systems

HS.ESS-SS Space Systems	
Connections to other DCIs in this grade-level: **HS.PS-NP, HS.PS-ER, HS.PS-E, HS.PS-FM, HS.PS-FE, HS.PS-IF**	
Articulation to DCIs across grade-levels: **1.PC, 5.SSS, MS.ESS-SS**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
RI.9-10.1	Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.
W.9-10.9(b)	Draw evidence from literary or informational texts to support analysis, reflection, and research.
W.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
W.11-12.9(b)	Draw evidence from literary or informational texts to support analysis, reflection, and research.
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with mathematics
MP.5	Use appropriate tools strategically
S.ID	Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies
G.MG	Apply geometric concepts in modeling situations
F.IF	Interpret functions that arise in applications in terms of the context
F.BF	Build a function that models a relationship between two quantities
F.LE	Construct and compare linear, quadratic, and exponential models and solve problems

HS.ESS-HE History of Earth

.ESS-HE History of Earth

Students who demonstrate understanding can:

a. **Analyze determined or hypothetical isotope ratios within Earth materials to make valid and reliable scientific claims about the planet's age, the ages of Earth events and rocks, and the overall time scale of Earth's history.** [Assessment Boundary: Radiometric dating techniques using complex methods such as multiple isotope ratios are not included.]

b. **Construct an explanation, using plate tectonic theory, for the general trends of the ages of continental and oceanic crust and the patterns of topographic features.** [Clarification Statement: Trends of crustal ages involve the youngest seafloor rocks located at mid-ocean ridges and the oldest ocean rocks often located near continental boundaries, with age bands of rocks parallel across mid-ocean ridges. Major topographic features are ocean ridges, trenches, and hot spot islands.]

c. **Construct explanations about changes that occurred to Earth during the Hadean Eon based on data from Earth materials, planetary surfaces, and meteorites.** [Clarification Statement: Dynamic Earth processes have destroyed most of Earth's very early rock record; however, lunar rocks, asteroids, and meteorites have remained relatively unchanged and provide evidence for conditions during Earth's earliest time periods.]

d. **Construct scientific arguments to support the claim that dynamic causes, effects, and feedbacks among Earth's systems result in a continual coevolution of Earth and the life that exists on it.** [Assessment Boundary: Students examine examples of feedbacks between Earth's different systems to understand how life has coevolved with Earth's surface (e.g., the atmosphere and biosphere affect the conditions for life, which in turn affects the composition of the atmosphere.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

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

Engaging in Argument from Evidence
Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth

- Radioactive-decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geologic time. (a)
- 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. (b)
- Although active geologic 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 can provide information about Earth's formation and early history. (c)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- 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. (b)
- Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. (b)

ESS2.E Biogeology

- The many dynamic and delicate feedbacks among the biosphere, geosphere, hydrosphere, and atmosphere cause a continual co-evolution of Earth's surface and the life that exists on it. (d)

Crosscutting Concepts

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). (a)

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. (b),(c),(d)

Connections to other DCIs in this grade-level: **HS.LS-IVT, HS.LS-NSE, HS.LS-MEOE, HS.LS-IRE, HS.PS-SPM, HS.PS-NP, HS.PS-CR, HS.PS-E**

Articulation to DCIs across grade-levels: **K.OTE, 2.IOS, 2.ECS, 4.PSE, MS.ESS-HE**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.9-10.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
WHST.9-10.1 Write arguments focused on discipline-specific content.
W.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
W.11-12.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
WHST.11-12.1 Write arguments focused on discipline-specific content.
W.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
SL.11-12.2 Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

Mathematics –

MP.2 Reason abstractly and quantitatively
MP.3 Construct viable arguments and critique the reasoning of others.
MP.5 Use appropriate tools strategically
S.ID Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.ESS-ES Earth's Systems

HS.ESS-ES Earth's Systems

Students who demonstrate understanding can:

a. **Apply scientific reasoning to explain how geophysical, geochemical, and geothermal evidence was used to develop the current model of Earth's interior.** [Clarification Statement: Evidence should include drill cores, gravity, seismic waves, and laboratory experiments on Earth materials.]

b. **Use a model of Earth's interior and the mechanisms of thermal convection to explain the cycling of matter and the impact of plate tectonics on Earth's surface.** [Assessment Boundary: Convection mechanisms should include heat from radioactive decay and gravity acting on materials of different densities as the drivers of convection and tectonic activity.]

c. **Analyze the impact of water on the flow of energy and the cycling of matter within and among Earth systems.** [Assessment Boundary: Should explore the unique physical and chemical properties of water, such as the polar nature of the molecule and water's ability to absorb/store/release energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.]

d. **Use Earth system models to explain how Earth's internal and surface processes work together at different spatial and temporal scales to form landscapes and sea floor features.**

e. **Construct an evidence-based claim about how a change to one part of an Earth system creates feedbacks that causes changes in other systems (e.g., coastal dynamics, watersheds and reservoirs, stream flow and erosion rates, changes in ecosystems).**

f. **Use mathematical expressions of phenomena to simulate how temperature, relative humidity, air pressure, and the dew point vary from the windward to the leeward side of a mountain range.** [Clarification Statement: The phenomena include latent heat, adiabatic heating/cooling, absolute/relative humidity, and dew point.]

g. **Use models to analyze data to make claims about how energy from the sun is redistributed throughout the atmosphere.** [Clarification Statement: Unequal heating of the atmosphere results in high and low pressure systems; air moves from areas of high pressure to low pressure; clockwise and counter-clockwise atmospheric circulations develop in response to Earth's rotation (the Coriolis Effect).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (b),(d),(g)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (c)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (f)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (a)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems

- Evidence from drill cores, gravity, seismic waves, and laboratory experiments on Earth materials, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of geophysical and geochemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, and a solid mantle and crust. (a)
- 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 increased downward gravitational pull on denser mantle materials. (b)
- Earth's systems interact over a wide range of temporal and spatial scales and continually react to changing influences, including those from human activities. Components of Earth's systems may appear stable, change slowly over long periods of time, or change abruptly. Changes in part of one system can cause dynamic feedbacks that can increase or decrease the original changes, further changing that system or other systems in ways that are often surprising and complex. (d),(e)
- Weather is driven by interactions of the geosphere, hydrosphere, and atmosphere. (f),(g)

ESS2.B: Plate Tectonics and Large-Scale System Interactions

- 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. (b)

ESS2.C: The Roles of Water in Earth's Surface Processes

- 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/release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks. (c)

Crosscutting Concepts

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. (a)

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. (d),(e)

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—it 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. (b),(c),(f),(g)

HS.ESS-ES Earth's Systems

.ESS-ES Earth's Systems	
..nnections to other DCIs in this grade-level: **HS.LS-MEOE, HS.LS-IRE, HS.PS-SPM, HS.PS-CR, HS.PS-ER, HS.PS-E, HS.PS-FM, HS.PS-FE, HS.PS-IF**	
Articulation to DCIs across grade-levels: **K.OTE, K.WEA, 2.IOS, 2.ECS, 3.WCI, 4.PSE, 5.ESI, MS.ESS-EIP, MS.ESS-ESP**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.9-10.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
W.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
RST.9-10.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
W.11-12.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
W.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
RST.11-12.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with mathematics
MP.5	Use appropriate tools strategically
S.ID	Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.ESS-CC Climate Change

HS.ESS-CC Climate Change

Students who demonstrate understanding can:

a. **Evaluate and communicate the climate changes that can occur when certain components of the climate system are altered.** [Clarification Statement: For example, evaluate variations in incoming solar radiation as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems.]

b. **Construct a scientific argument showing that changes to any one of many different Earth and Solar System processes can affect global and regional climates.** [Clarification Statement: Examples of these processes include the sun's energy output, Earth's orbit and axis orientation, tectonic events, ocean circulation, volcanic activity, glacial activity, the biosphere, and human activities.] [Assessment Boundary: Use evidence from the geologic record only.]

c. **Analyze geologic evidence that past climate changes have occurred over a wide range of time scales.** [Clarification Statement: Examples of evidence are ice core data, the fossil record, sea level fluctuations, glacial features.]

d. **Engage in critical reading of scientific literature about causes of climate change over 10s-100s of years, 10s-100s of thousands of years, or 10s-100s of millions of years.** [Clarification Statement: Examples of causes are changes in solar output, ocean circulation, volcanic activity (10s-100s of years); changes to Earth's orbit and the orientation of its axis (10s-100s of thousands of years); or long-term changes in atmospheric composition (10s-100s of millions of years).]

e. **Use global climate models in combination with other geologic data to predict and explain how human activities and natural phenomena affect climate, providing the scientific basis for planning for humanity's future needs.** [Clarification Statement: For example, use global climate models together with topographic maps to investigate effects of sea level change or combine global climate models with precipitation maps to investigate locations where new water supplies will be needed.]

f. **Apply scientific knowledge to investigate how humans may predict and modify their impacts on future global climate systems (e.g., investigating the feasibility of geoengineering design solutions to global temperature changes).**

g. **Use models of the flow of energy between the sun and Earth's atmosphere and surface to explain how different wavelengths of energy are absorbed and retained by various greenhouse gases in Earth's atmosphere, thereby affecting Earth's radiative balance.** [Clarification Statement: Students will work with absorption spectra of different Earth materials.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

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

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (f)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (b)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (a),(d)

Disciplinary Core Ideas

ESS2.D: Weather and Climate

- The foundation for Earth's global climate systems 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 these systems are altered. (a)
- 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. (b),(c),(d)
- Geologic 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 graduate 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 (link to ESS3.D). (b),(c),(d)
- 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. Global climate models incorporate scientists' best knowledge of the physical and chemical processes and of the interactions of relevant systems. They are tested by their ability to fit past climate variations. (e)
- Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. Hence the outcomes depend on human behaviors (link to ESS3.D) as well as on natural factors that involve complex feedbacks among Earth's systems (link to ESS3.A). (f)

ESS3.D: Global Climate Change

- Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (g)
- 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. (g)

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. (e),(g)

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. (a),(b),(c),(d)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (f)

HS.ESS-CC Climate Change

HS.ESS-CC Climate Change

Connections to other DCIs in this grade-level: **HS.LS-MEOE, HS.LS-IRE, HS.PS-ER, HS.PS-W, HS.PS-E**

Articulation to DCIs across grade-levels: **K.WEA, K.OTE, 3.WCI, 5.ESI, MS.ESS-WC, MS.ESS-HI**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.9-10.9(b) Draw evidence from literary or informational texts to support analysis, reflection, and research.
W.9-10.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
WHST.9-10.1 Write arguments focused on discipline-specific content.
SL.9-10.1.c Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.
W.11-12.9(b) Draw evidence from literary or informational texts to support analysis, reflection, and research.
W.11-12.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
WHST.11-12.1 Write arguments focused on discipline-specific content.
SL.11-12.1.c Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.

Mathematics –

MP.2 Reason abstractly and quantitatively
MP.3 Construct viable arguments and critique the reasoning of others
MP.4 Model with mathematics
S.ID Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
F.LE Construct and compare linear, quadratic, and exponential models and solve problems
S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.ESS-HS Human Sustainability

HS.ESS-HS Human Sustainability

Students who demonstrate understanding can:

a. **Construct arguments for how the developments of human societies have been influenced by natural resource availability including: locations of streams, deltas, and high concentrations of minerals, ores, coal, and hydrocarbons.**

b. **Reflect on and revise design solutions for local resource development that would increase the ratio of benefits to costs and risks to the community and its environment.** [Clarification Statement: Examples of local resource development include soil use for agriculture, water use, mining for coal and minerals, pumping for oil and natural gas.]

c. **Construct scientific claims for how increases in the value of water, mineral, and fossil fuel resources due to increases in population and rates of consumption have sometimes led to the development of new technologies to retrieve resources previously thought to be economically or technologically unattainable.**

d. **Construct scientific arguments from evidence to support claims that natural hazards and other geologic events have influenced the course of human history.** [Clarification Statement: Famines that result from reduced global temperatures can follow large historic volcanic eruptions. Large earthquakes and tsunamis can destroy cities, and there is a strong correlation between historic climate changes and the number of wars.]

e. **Construct scientific claims about the impacts of human activities on the frequency and intensity of some natural hazards.** [Clarification Statement: Natural hazards to include floods, droughts, forest fires, landslides, etc.]

f. **Identify mathematical relationships using data on the rates of production and consumption of natural resources in order to assess the global sustainability of human society.** [Assessment Boundary: Students construct equations for linear relationships, but not expected to construct equations for non-linear relationships.]

g. **Construct arguments about how engineering solutions have been and could be designed and implemented to mitigate local or global environmental impacts.** [Clarification Statement: Environmental impacts to include acid rain, water pollution, the ozone hole, etc.]

h. **Use results from computational General Circulation Models (GCMs) to investigate how the hydrosphere, atmosphere, geosphere, and biosphere are being modified in response to human activities.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (h)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Students also use and create simple computational simulations based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (f)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

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

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (a)
- Criticize and evaluate arguments and design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (b)

Disciplinary Core Ideas

ESS3.A: Natural Resources

- Resource availability has guided the development of human society. Resource availability affects geopolitical relationships and can limit development. (a)
- 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 social regulations can change the balance of these factors. (b)
- 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. (c)

ESS3.B: Natural Hazards

- Natural hazards and other geologic events have shaped the course of human history by destroying buildings and cities, eroding land, changing the courses of rivers, and reducing the amount of arable land. These events have significantly altered the sizes of human populations and have driven human migrations. (d)
- 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. (e)

ESS3.C: Human Impacts on Earth Systems

- The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources. (f)
- 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 over Antarctica). (g)
- Through computer simulations and other studies, important discoveries are still being made about how the ocean, atmosphere, and biosphere interact and are modified in response to human activities. (h)

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. (d),(h)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering and Technology

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (c)

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (a),(b),(e),(f),(g)

HS.ESS-HS Human Sustainability

.ESS-HS Human Sustainability	
Connections to other DCIs in this grade-level: **HS.LS-IRE, HS.PS-CR, HS.PS-E, HS.ETS-ETSS**	
Articulation to DCIs across grade-levels: **K.WEA, 3.WCI, 4.PSE, 4.E, MS.ESS-WC, MS.ESS-EIP, MS.ESS-ESP, MS.ESS-HI**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.9-10.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
W.9-10.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
W.9-10.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
WHST.9-10.1	Write arguments focused on discipline-specific content.
W.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data
W.11-12.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
W.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
WHST.11-12.1	Write arguments focused on discipline-specific content.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.3	Construct viable arguments and critique the reasoning of others
MP.4	Model with mathematics
F.IF	Interpret functions that arise in applications in terms of the context
F.BF	Build a function that models a relationship between two quantities
F.LE	Construct and compare linear, quadratic, and exponential models and solve problems
G.MG	Apply geometric concepts in modeling situations
A-CED.1	Create equations that describe numbers or relationships
S.ID	Summarize, represent, and interpret data on a single count or measurement variable; Summarize, represent, and interpret data on two categorical and quantitative variables
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.PS-SPM Structure and Properties of Matter

HS.PS-SPM Structure and Properties of Matter

Students who demonstrate understanding can:

a. Construct models showing that stable forms of matter are those with minimum magnetic and electrical field energy. [Clarification Statement: Examples of stable forms of matter can include noble gas atoms, simple molecules, and simple ionic substances.] [Assessment Boundary: Only for common substances- for example, water, carbon dioxide, common hydrocarbons, sodium chloride.]

b. Construct various types of models showing that energy is needed to take molecules apart and that energy is released when the atoms come together to form new molecules. [Assessment Boundary: Only for common substances (e.g., water, carbon dioxide, common hydrocarbons, sodium chloride]

c. Develop explanations about how the patterns of electrons in the outer level of atoms, as represented in the periodic table, reflect and can predict properties of elements. [Clarification Statement: An example of a pattern that predicts element properties is the first column of the periodic table: These elements all have one electron in the outer most energy level and as such are all highly reactive metals.] [Assessment Boundary: Only for main group elements (not transition metals or elements beyond the third row).]

d. Construct arguments for which type of atomic and molecular representation best explains a given property of matter. [Clarification Statement: Types of atomic and molecular representations can include computer-based, simulations, physical, ball and stick, and symbolic. Properties of matter can include reactivity, and polar vs. non-polar.] [Assessment Boundary: Not theoretical models]

e. Analyze and interpret data obtained from measuring the bulk properties of various substances to explain the relative strength of the interactions among particles in the substance. [Clarification Statement: Bulk properties of substances can include melting point and boiling point.] [Assessment Boundary: Comparisons between ionic and molecular species or network and molecular species are included, but those that require understanding of different intermolecular forces are not included. Only the following types of particles are included in data and explanations: atoms, ions, and molecules.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (b)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (a)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (e)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

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

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the merits of competing arguments, design solutions and/or models. (d)
- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (c),(d)
- 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. (c)
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (e)
- Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (a),(b)

PS2.B: Types of Interactions

- 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. (d),(e)

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. (a),(b),(c),

- [Clarification Statement for a: Stability is caused by minimization of energy.]
- [Clarification Statement for c: The likelihood of interactions between elements is caused by the number of electrons in their valence shell, and thus the arrangement of the periodic table.]

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. (d)

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. (e)

- [Clarification Statement for e: The relative strength of interactions among particles causes different bulk properties.]

Connections to other DCIs in this grade-level: **HS.LS-MEOE, HS.ESS-SS, HS.ESS-ES**

Articulation to DCIs across grade-levels: **MS.PS-SPM**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.8	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.
RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), nothing when the findings support or contradict previous explanations or accounts.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Mathematics –

MP.4	Model with mathematics.
8.F	Use functions to model relationships between quantities
S.ID	Summarize, represent, and interpret data on two categorical and quantitative variables
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.PS-CR Chemical Reactions

.PS-CR Chemical Reactions

..udents who demonstrate understanding can:

a. **Analyze and interpret data to support claims that energy of molecular collisions and the concentration of the reacting particles affect the rate at which a reaction occurs.** [Assessment Boundary: Limited to simple (zero or first order in each reactant) reactions. The exact relationship between rate and temperature is not required.]

b. **Develop and use models to explain that atoms (and therefore mass) are conserved during a chemical reaction.** [Clarification Statement: Models can include computer models, ball and stick models, and drawings.] [Assessment Boundary: Stoichiometric calculations are not required.]

c. **Analyze and interpret data to make claims that reaction conditions can be used to optimize the output of a chemical process.** [Assessment Boundary: Limited to simple reactions. Reaction conditions are limited to temperature, pressure, and concentrations of all substances in the system.]

d. **Construct mathematical models to explain how energy changes in chemical reactions are caused by changes in binding energy as the reactants form products and in which changes in the kinetic energy of the system can be detected as change in temperature.** [Assessment Boundary: Limited to calculating the change in binding energy and resulting change in thermal energy for simple chemical reactions, (i.e., reactions of simple hydrocarbons with oxygen).]

e. **Construct and communicate explanations using the structure of atoms, trends in the periodic table and knowledge of the patterns of chemical properties to predict the outcome of simple chemical reactions.** [Assessment Boundary: Only those chemical reactions readily predictable from the element's position on the periodic table and combustion reactions are intended.]

f. **Construct and communicate explanations that show how chemical processes and/or properties of materials are central to biological and geophysical systems.** [Clarification Statement: Chemical processes can include oxidation of hydrocarbons, and the reaction of CO_2 and H_20 to give hydrocarbons. Properties of materials can include water expanding when freezing.] [Assessment Boundary: Restricted to overall chemical processes (for example, oxidation of carbon compounds), or construction of carbon compounds (photosynthesis); details of biochemical pathways are not required (for example, Krebs Cycle).]

g. **Use system models (computer or drawings) to construct molecular-level explanations to predict the behavior of systems where a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.** [Assessment Boundary: Limited to simple reactions, adding or removing one reactant or product at a time.]

h. **Construct explanations using data from system models or simulations to support the claim that systems with many molecules have predictable behavior, but that the behavior of individual molecules is unpredictable.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain ...tionships between systems and their components in the ...ural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (b)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (b),(g)
- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (d)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (a),(c)
- Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. (a),(c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Make quantitative claims regarding the relationship between dependent and independent variables. (h)
- Apply scientific reasoning, theory, and models to link evidence to claims and show why the data are adequate for the explanation or conclusion. (h)
- Construct and revise explanations and arguments based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories) and peer review. (e),(f)

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- 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, with consequent changes in total binding energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy. (a),(d)
- 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. (c),(g)
- 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. (b),(e)
- Chemical processes and properties of materials underlie many important biological and geophysical phenomena. (f)

PS2.C: Stability and Instability in Physical Systems

- When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). (h)

PS3.A: Definitions of Energy

- "Chemical energy" generally is used to mean the energy that can be released or stored in chemical processes, and "electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. 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. (d)

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. (e),(f)

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. (a),(b),(c),(d),(h)

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—it 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. (g)

- [Clarification Statement for g: Dynamic and condition-dependent balances are dependent on matter and energy flows.]

HS.PS-CR Chemical Reactions

HS.PS-CR Chemical Reactions *(continued)*	
Connections to other DCIs in this grade-level: **HS.ETS-ED, HS.LS-SFIP, HS.LS-MEOE, HS.ESS-ES**	
Articulation to DCIs across grade-levels: **MS.PS-CR**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.8.8	Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
Mathematics –	
MP.2	Reason abstractly and quantitatively.
MP.4	Model with Mathematics
8.SP	Investigate patterns of association in bivariate data.
S.ID	Summarize, represent, and interpret data on a single count or measurement variable
A-CED.1	Create equations that describe numbers or relationships

HS.PS-E Energy

PS-E Energy

...udents who demonstrate understanding can:

a. Construct and defend models and mathematical representations that show that over time the total energy within an isolated system is constant, including the motion and interactions of matter and radiation within the system. [Assessment Boundary: Computational accounting for energy in a system limited to systems of two or three components.]

b. Identify problems and suggest design solutions to optimize the energy transfer into and out of a system. [Clarification Statement: Design solution examples can include insulation, microchip temperature control, cooking electronics, and roller coaster design.] [Assessment Boundary: Limited to mechanical and thermal systems.]

c. Analyze data to support claims that closed systems move toward more uniform energy distribution.

d. Design a solution to minimize or slow a system's inclination to degrade to identify the effects on the flow of the energy in the system. [Clarification Statement: Examples of system degradation can include wearing down due to friction, increase in disorder, and radioactive decay.]

e. Construct models to show that energy is transformed and transferred within and between living organisms. [Assessment Boundary: Does not mean particular biological processes such as Krebs cycle.]

f. Construct models to represent and explain that all forms of energy can be viewed as either the movement of particles or energy stored in fields. [Assessment Boundary: Models representing field energies need not be mathematical.]

g. Construct representations that show that some forms of energy may be best understood at the molecular or atomic scale. [Clarification Statement: Forms of energy represented can include thermal, electromagnetic, and sound.] Assessment Boundary: Limited to conceptual understanding; quantitative representations are not required.]

h. Design, build, and evaluate devices that convert one form of energy into another form of energy. [Clarification Statement: Examples of devices can include roller coasters, Rube Goldberg devices, wind turbines, and generators.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*.

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.

- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (b)

Developing and Using Models
...deling in 9–12 builds on K–8 and progresses to using, ...thesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use multiple types of models to represent and explain phenomena and move flexibly between model types based on merits and limitations. (a),(f)
- Construct, revise, and use models to predict and explain relationships between systems and their components. (e),(g)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (c)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical or algorithmic representations of phenomena or design solutions to create explanation, computational models, or simulations. (a)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with ...ntific knowledge, principles, and theories.

- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (b),(d),(h)

Disciplinary Core Ideas

PS3.A: Definitions of Energy

- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. (a)
- 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. (a),(e),(h)
- 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. (h)
- 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. (f),(g)

PS3.B: Conservation of Energy and Energy Transfer

- 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. (a),(h)
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (b),(c),(e),(h)
- 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. (a),(c)
- The availability of energy limits what can occur in any system. (d)
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (c),(d),(e)
- Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes). (d)

PS3.D: Energy in Chemical Processes

- The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (e)
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (h)
- A variety of multistage physical and chemical processes in living organisms, particularly within their cells, account for the transport and transfer (release or uptake) of energy needed for life functions. (e)
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing the task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (b),(h)

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. (a),(c),(d),(e),(f),(g),(h)

- [Clarification Statement for all PEs: Energy transfer cannot be directly studied- a model must be used. In design for maximal or minimal energy transfer, the boundaries of a system must be defined]

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (b)

HS.PS-ECT Energy *(continued)*	
Connections to other DCIs in this grade-level: **HS.LS-SFIP, HS.LS-MEOE, HS.ESS-CC, HS.ESS-HS, HS.ESS-ES, HS.ESS-SS, HS.ETS-ED, HS.ETS-ETSS**	
Articulation to DCIs across grade-levels: **MS.PS-E, MS.PS-CR**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
SL.1.c	Propel conversations by posing and responding to questions that probe reasoning and evidence; ensure a hearing for a full range of positions on a topic or issue; clarify, verify, or challenge ideas and conclusions; and promote divergent and creative perspectives.
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source.
RST.9-10.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
RST.11-12.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
Mathematics –	
MP.2	Reason abstractly and quantitatively.
MP.3	Construct viable arguments and critique the reasoning of others
MP.4	Model with Mathematics
MP.6	Attend to precision
A-REI.10	Represent and solve equations and inequalities graphically.
A.SSE	Interpret the structure of expressions.
A.CED	Create equations that describe numbers or relationships.

HS.PS-FM Forces and Motion

PS-FM Forces and Motion

.dents who demonstrate understanding can:

a. Plan and carry out investigations to show that the algebraic formulation of Newton's second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion. [Assessment Boundary: Restricted to one- and two-dimensional motion and does not include rotational motion. Does not apply in the case of subatomic scales or for speeds close to the speed of light. Calculations restricted to macroscopic objects moving at non-relativistic speeds.]

b. Generate and analyze data to support the claim that the total momentum of a closed system of objects before an interaction is the same as the total momentum of the system of objects after an interaction. [Clarification Statement: Conservation of momentum is the focus.]

c. Use algebraic equations to predict the velocities of objects after an interaction when the masses and velocities of objects before the interaction are known. [Assessment Boundary: Restricted to macroscopic interactions and only two objects moving in one or two dimensions.]

d. Design and evaluate devices that minimize the force on a macroscopic object during a collision.

e. Construct a scientific argument supporting the claim that the predictability of changes within systems can be understood by defining the forces and changes in momentum both inside and outside the system. [Assessment Boundary: Restricted to macroscopic interactions.]

f. Communicate arguments to support claims that Newton's laws of motion apply to macroscopic objects but not to objects at the subatomic scales or speeds close to the speed of light. [Assessment Boundary: No details of quantum physics or relativity are included.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

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.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (b)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (c)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

- Apply scientific knowledge to solve design problems by taking into account possible unanticipated effects. (d)
- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (d)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (e),(f)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- 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. (a),(e),(f)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (b)
- In any system, total momentum is always conserved. (b),(c)
- 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. (c),(d),(e)

PS2.C: Stability and Instability in Physical Systems

- Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from outside, helps predict its behavior under a variety of conditions. (d),(e)

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. (a),(c),(d)

Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (b),(e)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (d)

HS.PS-FM Forces and Motion

HS.PS-FM Forces and Motion *(continued)*	
Connections to other DCIs in this grade-level: **HS.ETS-ED, HS.ESS-SS, HS.ESS-ES**	
Articulation to DCIs across grade-levels: **MS.PS-FM, MS.PS-WER**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
WHST.9	Draw evidence from informational texts to support analysis, reflection, and research.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with Mathematics
MP.5	Use appropriate tools strategically
8.F	Define, evaluate, and compare functions.
S.ID	Summarize, represent, and interpret data on a single count or measurement variable
F.BF	Build a function that models a relationship between two quantities
N-Q	Reason quantitatively and use units to solve problems

HS.PS-FE Forces and Energy

PS-FE Forces and Energy

..udents who demonstrate understanding can:

a. Plan and carry out investigations in which a force field is mapped to provide evidence that forces can transmit energy across a distance. [Assessment Boundary: Mapping limited to the direction of the force field.]

b. Develop arguments to support the claim that when objects interact at a distance, the energy stored in the field changes as the objects change relative position. [Clarification Statement: An example of this phenomenon could include repelling magnets moving apart, reducing the repelling force and the strength of the field between them.] [Assessment Boundary: Qualitative comparisons only.]

c. Evaluate natural and designed systems where there is an exchange of energy between objects and fields and characterize how the energy is exchanged. [Clarification Statement: Examples of these systems could include motors, generators, speakers, microphones, planets orbiting a start.] [Assessment Boundary: Characterizations limited to qualitative descriptors.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

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.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Evaluate the claims, evidence, and reasoning of currently accepted explanations or solutions as a basis for the merits of the arguments. (b)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability the claims, methods, and designs.

- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (c)

Disciplinary Core Ideas

PS3.C: Relationship Between Energy and Forces

- Force fields (gravitational, electric, and magnetic) contain energy and can transmit energy across space from one object to another. (a)
- When two objects interacting through a force field change relative position, the energy stored in the force field is changed. (b),(c)
- Each force between the two interacting objects acts in the direction such that motion in that direction would reduce the energy in the force field between the objects. However, prior motion and other forces also affect the actual direction of motion. (c)

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 identity some patterns. (a),(b)

- [Clarification Statement for a: Mapping force fields requires evidence of the pattern of the field lines]
- [Clarification Statement for b: Coulomb's law: Proportion is a pattern.]
- [Clarification Statement for c: A pattern of energy transfer will be apparent.]

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (c)

Connections to other DCIs in this grade-level: **HS.ESS-SS, HS.ESS-ES, HS.ESS-CC, HS.ETS-ETSS**

Articulation to DCIs across grade-levels: **MS.PS-E**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with Mathematics.

F.BF Build a function that models a relationship between two quantities.

A.CED Create equations that describe numbers or relationships.

HS.PS-IF Interactions of Forces

HS.PS-IF Interactions of Forces

Students who demonstrate understanding can:

- **a. Use mathematical expressions to determine the relationship between the variables in Newton's Law of Gravitation and Coulomb's Law, and use these to predict the electrostatic and gravitational forces between objects.** [Assessment Boundary: Only situations with two objects are predicted.]
- **b. Use models to demonstrate that electric forces at the atomic scale affect and determine the structure, properties (including contact forces), and transformations of matter.** [Clarification statement: Models can include graphical and computer models. Examples of properties and transformations of matter can include intermolecular forces, chemical bonding, and enzyme-substrate interaction.] [Assessment Boundary: Only a qualitative understanding is expected.]
- **c. Plan and carry out investigations to demonstrate the claim that magnets, electric currents, or changing electric fields cause magnetic fields and electric charges or changing magnetic fields cause electric fields.** [Assessment Boundary: Qualitative observations only.]
- **d. Obtain, evaluate, and communicate information to show that strong and weak nuclear interactions inside atomic nuclei determine which nuclear isotopes are stable, and that the pattern of decay of an unstable nucleus can often be predicted.** [Clarification Statement: Types of decay in unstable nuclei can include alpha or beta radiation.] [Assessment Boundary: Only a qualitative understanding of nuclear interactions is expected.]
- **e. Obtain, evaluate, and communicate information to show how scientists and engineers take advantage of the effects of electrical and magnetic forces in materials to design new devices and materials through a process of research and development.** [Clarification Statement: Designed devices can include magnetic strips on credit cards, laser printers, and photo copiers.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Construct, revise, and use models to predict and explain relationships between systems and their components. (b)

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.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects and ensure the investigation's design has controlled for them. (c)

Using Mathematical and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (a)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Generate, synthesize, communicate, and critique claims, methods and designs that appear in scientific and technical texts or media reports. (d),(e)

Disciplinary Core Ideas

PS2.B: Types of Interactions

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (a)
- 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. (c)
- 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. (b),(e)
- The strong and weak nuclear interactions are important inside atomic nuclei—for example, they determine the patterns of which nuclear isotopes are stable and what kind of decays occur for unstable ones. (d)

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 desire effect. Changes in systems may have various causes that may not have equal effects. (a),(b),(c),(d)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Science and engineering complement each other in the cycle known as research and development (R&D). Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (e)

Connections to other DCIs in this grade-level: **HS.ETS-ETSS, HS.ESS-SS, HS.ESS-ES**

Articulation to DCIs across grade-levels: **MS.PS-IF, MS.PS-FM**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively

MP.4 Model with Mathematics

8.F Define, evaluate, and compare functions.

S.ID Summarize, represent, and interpret data on a single count or measurement variable

F.BF Build a function that models a relationship between two quantities

HS.PS-W Waves

PS-W Waves

Students who demonstrate understanding can:

a. Plan and carry out investigations to determine the mathematical relationships among wave speed, frequency, and wavelength and how they are affected by the medium through which the wave travels. [Assessment Boundary: Algebraic calculations only.]

b. Carry out an investigation to describe a boundary between two media that affects the reflection, refraction, and transmission of waves crossing the boundary. [Clarification Statement: Descriptions should include mathematical relationships.] [Assessment Boundary: Descriptions requiring trigonometric functions are excluded.]

c. Investigate the patterns created when waves of different frequencies combine and explain how these patterns are used to encode and transmit information. [Assessment Boundary: Qualitative only.]

d. Use drawings, physical replicas, or computer simulation models to explain that resonance occurs when waves add up in phase in a structure, and that structures have a unique frequency at which resonance occurs. [Clarification Statement: Constructive and destructive interference of waves results in a standing wave pattern (resonance).] [Assessment Boundary: Qualitative explanations only.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Use models (including mathematical and computational) to generate data to explain and predict phenomena, analyze systems, and solve problems. (d)

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.

- Plan and carry out investigations individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (a),(b),(c)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (b)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

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

Disciplinary Core Ideas

PS4.A: Wave Properties

- 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. (a),(b)
- Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. (c)
- 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. (d)

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 identity some patterns. (a),(c),(d)

- [Clarification Statement for d: Constructive and destructive interference of waves results in a standing wave pattern, i.e. resonance.]

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. (b)

Connections to other DCIs in this grade-level: **HS-ETS-ETSS, HS-ETS-ED, HS.ESS-ES**

Articulation to DCIs across grade-levels: **MS.PS-WER**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

W.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with Mathematics.

F.LE Construct and compare linear, quadratic, and exponential models and solve problems.

A-REI.10 Represent and solve equations and inequalities graphically.

A.CED Create equations that describe numbers or relationships.

HS.PS-ER Electromagnetic Radiation

HS.PS-ER Electromagnetic Radiation

Students who demonstrate understanding can:

a. **Use arguments to support the claim that electromagnetic radiation can be described using both a wave model and a particle model, and determine which model provides a better explanation of phenomena.** [Assessment Boundary: Limited to understanding that the quantum theory relates the two models, but students do not need to know the specifics of the quantum theory.]

b. **Obtain, evaluate, and communicate scientific literature to show that all electromagnetic radiation travels through a vacuum at the same speed (called the speed of light).**

c. **Obtain, evaluate, and communicate scientific literature about the effects different wavelengths of electromagnetic radiation have on matter when the matter absorbs it.** [Assessment Boundary: Only IR, UV, and gamma radiation are intended; qualitative descriptions only.]

d. **Analyze and interpret data of both atomic emission and absorption spectra of different samples to make claims about the presence of certain elements in the sample.** [Assessment Boundary: Identification of elements to be based on comparison of spectral lines.]

e. **Construct an explanation of how photovoltaic materials work using the particle model of light, and describe their application in everyday devices.** [Clarification Statement: Everyday devices can include solar cells and barcodes.] [Assessment Boundary: Qualitative descriptors only]

f. **Obtain, evaluate, and communicate scientific literature about the differences and similarities between analog and digital representations of information to describe the relative advantages and disadvantages.** [Assessment Boundary: Qualitative explanations only.]

g. **Construct explanations for why the wavelength of an electromagnetic wave determines its use for certain applications.** [Clarification Statement: Examples of wavelength determining applications can include visible light not being used to observe atoms, and x-rays being used for bone imaging.] [Assessment Boundary: Only qualitative descriptors in the explanation are intended.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and models (e.g computational and mathematical) to plan, gather, and analyze data to make valid and reliable scientific claims or justify an optimal solution. (d)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories.

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

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Construct a counter-argument that is based in data and evidence that challenges another proposed argument. (a)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on 6–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (b),(c),(f)

Disciplinary Core Ideas

PS4.A: Wave Properties

- 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. (f)

PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. Quantum theory relates the two models. (Boundary: Quantum theory is not explained further at this grade level.) (a)
- Because a wave is not much disturbed by objects that are small compared with its wavelength, visible light cannot be used to see such objects as individual atoms. (g)
- 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. (b),(g)
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). (c),(g)
- Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (c),(g)
- Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. (e)
- 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. (d)

PS4.C: Information Technologies and Instrumentation

- 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. (e),(f),(g)
- Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communication, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.) (g)

Crosscutting Concepts

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. (a),(b),(d),(e)

- [Clarification Statement for a: The way something functions, e.g. visible light, can be best understood through a particular representation of its structure.]
- [Clarification Statement for d: Rationale is that from the spectra (the way they function) the structure can be inferred.]

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c),(f),(g)

HS.PS-ER Electromagnetic Radiation

.PS-ER Electromagnetic Radiation *(continued)*
Connections to other DCIs in this grade-level: **HS.ETS-ETSS, HS.ESS-SS**
Articulation to DCIs across grade-levels: **MS.PS-WER**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **RI.9-10.8** Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is valid and the evidence is relevant and sufficient; identify false statements and fallacious reasoning. **SL.9-10.4** Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task. **SL.11-12.4** Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. *Mathematics –* **N-Q** Reason quantitatively and use units to solve problems **S.ID** Summarize, represent, and interpret data on a single count or measurement variable **S.IC** Make inferences and justify conclusions from sample surveys, experiments, and observational studies

HS.PS-NP Nuclear Processes

HS.PS-NP Nuclear Processes

Students who demonstrate understanding can:

a. Construct models to explain changes in nuclear energies during the processes of fission, fusion, and radioactive decay and the nuclear interactions that determine nuclear stability. [Assessment Boundary: Models to exclude mathematical representations. Radioactive decays limited to alpha, beta, and gamma.]

b. Analyze and interpret data sets to determine the age of samples (rocks, organic material) using the mathematical model of radioactive decay. [Assessment Boundary: Mathematical model limited to graphical representations.]

c. Ask questions and make claims about the relative merits of nuclear processes compared to other types of energy production. [Clarification Statement: Students are given data about energy production methods, such as burning coal versus using nuclear reactors.] [Assessment Boundary: Students only analyze data provided. Merits only include economic, safety, and environmental]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems

Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.

- Ask questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. (c)

Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and constructing models to predict and explain relationships between systems and their components in the natural and designed world.

- Construct, revise, and use models to predict and explain relationships between systems and their components. (a)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Use tools, technologies, and 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. (b),(c)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Students also use and create simple computational simulations based on mathematical models of basic assumptions.

- Use statistical and mathematical techniques and structure data (e.g., displays, tables, and graphs) to find regularities, patterns (e.g., fitting mathematical curves to data), and relationships in data. (b)

Disciplinary Core Ideas

PS1.C: Nuclear Processes

- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. (a) The total number of neutrons plus protons does not change in any nuclear process. (a)
- Strong and weak nuclear interactions determine nuclear stability and processes. (a)
- 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. (b)

PS3.D: Energy in Chemical Processes and Everyday Life

- All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. (c)

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. (a)

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. (b)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benefits while decreasing costs and risks. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c)

Connections to other topics in this grade-level: **HS.ESS-SS, HS.ESS-HE, HS.ETS-ETSS**

Articulation across grade-levels: **MS.PS-SPM, MS.LS-NSA**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

SL.1.c Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

W.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

W.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

Mathematics –

MP.4 Model with Mathematics

F.LE Construct and compare linear, quadratic, and exponential models and solve problems

A-CED.1 Create equations that describe numbers or relationships

N-Q Reason quantitatively and use units to solve problems

HS-ETS-ED Engineering Design

ETS-ED Engineering Design

Students who demonstrate understanding can:

a. **Ask questions and collect information to quantify the scope and impacts of a major global problem on local communities and find evidence of possible causes by breaking the problem down into parts and investigating the mechanisms that may contribute to each part.** [Clarification Statement: For example, students ask questions to quantify the scope and impacts of acid rain in a local community by investigating the mechanisms involved in stone monument erosion.] [Assessment Boundary: Limit to asking questions and gathering information to better understand the problem and possible causes; not finding solutions.]

b. **Analyze input and output data and functioning of a human-built system to define opportunities to improve the system's performance so it better meets the needs of end users while taking into account constraints (e.g., materials, costs, scientific principles).** [Clarification Statement: Analyze data and functioning of a human-built system such as a school's heating and cooling system; or throughput and functioning of a city's wastewater system.]

c. **Evaluate different solutions to a problem by identifying criteria (e.g., cost, safety, reliability, aesthetics) and possible impacts on society and the natural environment, and using a trade-off matrix or numerical weighting system to choose the best solution.** [Clarification Statement: Example problems for which multiple solutions can be proposed and evaluated include deicing a parking lot, increasing yield of a garden or farm, or mining a natural resource with minimal environmental damage.]

d. **Plan and carry out a quantitative investigation with physical models or prototypes to develop evidence on the effectiveness of design solutions, leading to at least two rounds of testing and improvement.** [Clarification Statement: For example, physical models or prototypes to conduct a quantitative investigation to determine if an ultraviolet light can purify water equally well as a chlorine-based system.]

e. **Use computational thinking to create, simulate, and compare different design solutions, checking to be certain that the simulation makes sense when compared with the real world.** [Clarification Statement: For example, students create a computer simulation of a model building to see how different modifications could save energy and reduce CO_2 emissions.] [Assessment Boundary: Students use existing modeling software.]

f. **Refine a solution by prioritizing criteria and taking into account the life cycle of a given product or technological system and factors such as safety, reliability, and aesthetics to achieve an optimal solution.** [Clarification Statement: For example, choose the best possible heat pump technology for a campus building; determine the optimum method for extracting oil and natural gas; or best method for treating soil prior to planting crops.]

The performance expectations above were developed using the following elements from the NRC *A Framework for K – 12 Science Education*:

Science and Engineering Practices

Asking Questions and Defining Problems
Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and explanatory models and simulations.
- Ask questions that arise from phenomena, models, theory, or unexpected results. (a)
- Ask questions to determine quantitative relationships between independent and dependent variables. (a)

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.
- Plan and carry out investigations collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure that the investigation's design has controlled for them. (d)
- Select appropriate tools to collect, record, analyze, and evaluate data. (d)

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Use tools, technologies, and 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. (b)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use simple limit cases to test mathematical expressions, computer programs or algorithms, or simulations to see if a model makes sense by comparing the outcomes with what is known about the real world. (e)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting an Engineering Problem
- Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product's or system's function (what job it will perform and how), its durability, and limits on its size and cost. (b)
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (b)
- Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges may also have manifestations in local communities. But, whatever the scale, the first things that engineers do is define the problem and specify the criteria and constraints for potential solutions. (a)

ETS1.B: Developing Possible Solutions
- To design something complicated one may need to break the problem into parts and attend to each part separately but must then bring the parts together to test the overall plan. (a)
- When evaluating 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. (c)
- Testing should lead to improvements in the design through an iterative procedure. Both physical models and computer models can be used in various ways to aid in the engineering design process. Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials. (d)
- Computer models are useful for a variety of purposes, such as in representing a design in 3-D through CAD software; in troubleshooting to identify and describe a design problem; in running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (e)

ETS1.C: Optimizing the Design Solution
- The aim of engineering design is not simply to find a solution to a problem but to design the best solution under the given constraints and criteria. Optimization can be complex for a design problem with numerous desired qualities or outcomes. Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (f)
- The comparison of multiple designs can be aided by a trade-off matrix. Sometimes a numerical weighting system can help evaluate a design against multiple criteria. When evaluating solutions, all relevant considerations, including cost, safety, reliability, and aesthetic, social, cultural, and environmental impacts, should be

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 huma 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. (a),(e)

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 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. (b),(c),(d)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. Engineers continuously modify these systems to increase benef while decreasing costs and risks. New technologies can have deep impacts on society and the environment,

HS-ETS-ED Engineering Design *(continued)*		
dent-generated sources of evidence consistent with scientific knowledge, principles, and theories. • Apply scientific knowledge to solve design problems by engaging in all steps of the design cycle, taking into account possible unanticipated effects. (f) **Engaging in Argument from Evidence** Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science. Evaluate the merits of competing arguments, design solutions and/or models. (c)	included. (c) Testing should lead to design improvements through an iterative process, and computer simulations are one useful way of running such tests. (d)	some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (c),(f)

Connections to other DCIs in this grade-level: **HS.ESS-CC, HS.ESS-HS, HS.PS-E, HS.ETS-ETSS**

Articulation to DCIs across grade-levels: **MS.ETS-ED**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

WHST.9 Draw evidence from informational texts to support analysis, reflection, and research.

Mathematics –

MP.2 Reason abstractly and quantitatively

MP.4 Model with Mathematics

MP.5 Use appropriate tools strategically

8.F Define, evaluate, and compare functions.

S.ID Summarize, represent, and Interpret data on a single count or measurement variable

S.IC Make inferences and justify conclusions from sample surveys, experiments, and observational studies

F.BF Build a function that models a relationship between two quantities

F.LE Construct and compare linear, quadratic, and exponential models and solve problems

N-Q Reason quantitatively and use units to solve problems

A.CED Create equations that describe numbers or relationships.

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

ETS-ETSS Links Among Engineering, Technology, Science, and Society

Students who demonstrate understanding can:

a. Plan and carry out an investigation to improve a technology and suggest ideas for further related scientific study. [Clarification Statement: For example, a group of students investigate the environmental conditions needed to maintain a healthy aquatic population, apply findings to improving an aquarium, and recommend research that can be done with the improved technology to study aquatic ecosystems.]

b. Gather evidence to evaluate different explanations for the widespread adoption of a modern technology, including the role of societal demands, market forces, evaluations by scientists and engineers, and possible government regulation. [Clarification Statement: For example, students evaluate explanations for the rapid spread of cell phones, LED lighting, or genetically engineered crops for farming.]

c. Analyze data to compare different technologies designed to accomplish the same function regarding their relative environmental impacts, costs, risks, and benefits, and what may need to be done to reduce unanticipated negative effects. [Clarification Statement: Comparisons include paper vs. electronic books, nuclear vs. coal-fired power plants.] [Assessment Boundary: Analysis limited to data available online or provided to students.]

d. Construct or critique arguments based on evidence concerning the costs, risks, and benefits of changes in major technological systems related to agriculture, health, water, energy, transportation, manufacturing, or construction, needed to support a growing world population. [Clarification Statement: For example, students construct arguments concerning the costs and benefits of shifting from centralized to distributed energy generation systems or natural to genetically engineered crops.] [Assessment Boundary: Limited to relative comparison of costs and benefits of different technological changes.]

The performance expectations above were developed using the following elements from the NRC *A Framework for K – 12 Science Education*:

Science and Engineering Practices

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.

- Plan and carry out investigations Individually and collaboratively and test designs as part of building and revising models, explaining phenomena, or testing solutions to problems. Consider possible confounding variables or effects, and ensure the investigation's design has controlled for them. (a)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze 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. (c)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science.

- Construct a counter-argument that is based in data and evidence that challenges another proposed argument. (d)
- Criticize and evaluate arguments and design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. (d)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluate the validity and reliability of the claims, methods, and designs.

- Critically read scientific literature adapted for classroom use to identify key ideas and major points and to evaluate the validity and reliability of the claims, methods, and designs. (b)
- Generate, synthesize, communicate, and critique claims, methods, and designs that appear in scientific and technical texts or media reports. (b)

Disciplinary Core Ideas

ETS2.A: Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). (a)
- Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise. (a)

ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World

- Modern civilization depends on major technological systems, including those related to agriculture, health, water, energy, transportation, manufacturing, construction, and communications. (d)
- Engineers continuously modify these technological systems by applying scientific and engineering knowledge and practices to increase benefits while decreasing costs and risks. (d)
- Widespread adoption of technological innovations often depends on market forces or other societal demands, but it may also be subject to evaluation by scientists and engineers and to eventual government regulation. (b)
- New technologies can have deep impacts on society and the environment, including some that were not anticipated or that may build up over time to a level that requires attention or mitigation. (c)
- Analysis of costs, environmental impacts, risks and benefits, are critical aspects of decisions about technology use. (c)

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. (a),(b)

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. (b),(c),(d)

HS-ETS-ETSS Links Among Engineering, Technology, Science, and Society

S-ETS-ETSS Links Among Engineering, Technology, Science, and Society ***(continued)***	
nnections to other DCIs in this grade-level: **HS.ESS-CC, HS.ESS-HS, HS.LS.IRE, HS.LS.NSE, HS.PS-ER, HS.PS-NP, HS.ETS-ED**	
Articulation to DCIs across grade-levels: **MS.ETS-ETSS**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
W.8.8	Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
WHST.9	Draw evidence from informational texts to support analysis, reflection, and research.
Mathematics –	
MP.2	Reason abstractly and quantitatively
MP.4	Model with Mathematics
MP.5	Use appropriate tools strategically
8.F	Define, evaluate, and compare functions.
S.ID	Summarize, represent, and interpret data on a single count or measurement variable
S.IC	Make inferences and justify conclusions from sample surveys, experiments, and observational studies
F.BF	Build a function that models a relationship between two quantities
N-Q	Reason quantitatively and use units to solve problems
MP.4	Model with Mathematics.
A.CED	Create equations that describe numbers or relationships.