NEXT GENERATION SCIENCE STANDARDS

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

Middle School

May 7, 2012

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

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Students who demonstrate understanding can:

a. **Investigate and present evidence that the structure of cells in both unicellular and multicellular organisms is related to how cells function.** [Assessment Boundary: Students conduct, not design, investigations.]

b. **Investigate and generate evidence that unicellular and multicellular organisms survive by obtaining food and water, disposing of waste, and having an environment in which to live.**

c. **Construct an explanation for the function of specific parts of cells including: nucleus, chloroplasts, and mitochondria and the structure of the cell membrane and cell wall for maintaining a stable internal environment.**

d. **Construct models and representations of body systems to demonstrate how multiple interacting subsystems and structures work together to accomplish specific functions.** [Clarification Statement: Representations are specific to the interactions of the systems and focus on the following systems: excretory, digestive, respiratory, and nervous systems.] [Assessment Boundary: The focus is on the interaction of subsystems within the system, not the mechanism of each body system itself.]

e. **Provide explanations of how sense receptors respond to stimuli by sending messages to the brain to be processed for immediate behavior or stored as information.**

f. **Communicate an explanation for how the storage of long-term memories requires changes in the structure and function of millions of interconnected nerve cells in the brain.**

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 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (a),(b)

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 scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (c),(e)
- Construct explanations from models or representations. (c)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluating the merit and validity of ideas and methods.

- Gather, read, and explain information from appropriate sources and evaluate the credibility of the publication, authors, possible bias of the source, and methods used. (f)

Disciplinary Core Ideas

LS1.A: Structure and Function

- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (a)
- Unicellular organisms (microorganisms), like multicellular organisms, need food, water, a way to dispose of waste, and an environment in which they can live. (b)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (c)
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (d)

LS1.D: Information Processing

- Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. (e)
- The signals are then processed in the brain, resulting in immediate behaviors or memories. Changes in the structure and functioning of many millions of interconnected nerve cells allow combined inputs to be stored as memories for long periods of time. (f)

Crosscutting Concepts

Systems and System Models

Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (b),(d),(e)

Structure and Function

Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (a),(c),(f)

Connections to other topics in this grade level: **MS.PS-CR**

Articulation across grade-levels: **3.SFS, HS.LS-SFIP**

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

ELA –

RST.6.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
RI.6.7 Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.
RI.6.8 Trace and evaluate the argument and specific claims in a text, distinguishing claims that are supported by reasons and evidence from claims that are not.
RI.7.8 Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims.
RI.8.8 Delineate and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient; recognize when irrelevant evidence is introduced.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.6 Attend to precision.
7.SP.1,2 Use random sampling to draw inferences about a population.

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

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

Students who demonstrate understanding can:

a. **Develop an explanation for the role of photosynthesis in the cycling of matter and flow of energy on Earth.** [Assessment Boundary: Limited to the explanation related to water, carbon dioxide, and light energy being used to produce sugars and release oxygen NOT the chemical equation for photosynthesis.]

b. **Investigate the cycling of matter among living and nonliving parts of ecosystems to explain the flow of energy and conservation of matter.** [Clarification Statement: Investigations are qualitative observations of the cycling of water, carbon, and oxygen in the environment.]

c. **Use models to explain the transfer of energy into, out of, and within ecosystems.** [Assessment Boundary: Only light, chemical, and thermal energy need to be addressed with an emphasis that the total amount of energy does not change.]

d. **Construct and communicate models of food webs that demonstrate the transfer of matter and energy among organisms within an ecosystem.** [Clarification Statement: Models of food webs should include producers, consumers and decomposers.]

e. **Use evidence to support an explanation that matter is conserved when molecules from food react with oxygen in the environment and cycle repeatedly between living and non-living components of ecosystem.**

f. **Use evidence to support arguments that changing any physical or biological component of an ecosystem may result in shifts in the populations of species in the ecosystem.**

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 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (c),(d)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions under a range of conditions. (b)

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 scientific knowledge, principles, and theories.

- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (a)
- Construct explanations from models or representations. (e)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (f)

Disciplinary Core Ideas

LS1.C: Organization for Matter and Energy Flow in Organisms

- Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (a)
- Animals obtain food from eating plants or eating other animals. (d)
- Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth or to release energy. (e)
- In most animals and plants, oxygen reacts with carbon-containing molecules (sugars) to provide energy and produce carbon-dioxide; anaerobic bacteria achieve their energy needs in other chemical processes that do not need oxygen. (c)

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

- Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (b),(c),(d)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (f)

Crosscutting Concepts

Systems and System Models-
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (c)

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (a),(b),(e)

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (d)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (f)

Connections to other topics in this grade-level: **MS.ESS-HE, MS.ESS-ESP, MS.PS-SPM, MS.PS-ECT, MS.PS-CR**

Articulation across grade-levels: **3.SFS, 5.MEE, HS.LS-MEOE, HS.LS-IRE**

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

ELA –

SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

W.6.8 Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.

W.7.8 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.

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others.
MP.4 Model with mathematics.
5.OA Analyze patterns and relationships.
6.SP Summarize and describe distributions.

MS.LS-IRE Interdependent Relationships in Ecosystems

MS.LS-IRE Interdependent Relationships in Ecosystems

Students who demonstrate understanding can:

- a. **Use a model to demonstrate the effect of resource availability on organisms and populations of organisms in an ecosystem.**
- b. **Construct explanations to describe competitive, predatory, and mutually beneficial interactions as patterns across various ecosystems.**
- c. **Ask researchable questions about the ways organisms obtain matter and energy across multiple and varied ecosystems.** [Assessment Boundary: Biochemical details of photosynthesis and cellular respiration are not to be treated in terms of mechanism.]
- d. **Use models to explain the role of biodiversity in ecosystems.**
- e. **Use evidence to construct arguments for how biodiversity can influence humans' resources as well as ecosystem services that humans rely on.** [Clarification Statement: Examples of humans' resources include food, energy, medicines. Ecosystem services can include water purification and recycling.]
- f. **Pose questions about patterns in social interactions and grouping behaviors of animals that contribute to survival advantages.**

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 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions.

- Ask questions that arise from phenomena, models, or unexpected results. (c),(f)

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)
- Modify models – based on their limitations – to increase detail or clarity, or to explore what will happen if a component is changed. (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 scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why data are adequate for the explanation or conclusion. (b)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (e)

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems

- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (a),(c)
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared. (b)

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health. (d)

LS2.D: Social Interactions and Group Behavior

- Groups may form because of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species-specific). They engage in a variety of signaling behaviors to maintain the group's integrity or to warn of threats. Groups often dissolve if they no longer function to meet individuals' needs, if dominant members lose their place, or if other key members are removed from the group through death, predation, or exclusion by other members. (f)

LS4.D: Biodiversity and Humans

- Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on Earth from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). (d)
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. (e)

Crosscutting Concepts

Patterns
Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (b),(f)

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(e)

Systems and System Models
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (d)

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (c)

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

Articulation across grade-levels: **3.EIO, 5.MEE, HS.LS-IRE, HS.LS-MEOE**

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

ELA –

SL.6.3 Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.
SL.7.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.
WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others.
5.OA Analyze patterns and relationships.
7.SP.3 Draw informal comparative inferences about two populations.

MS.LS-NSA Natural Selection and Adaptations

MS.LS-NSA Natural Selection and Adaptations

tudents who demonstrate understanding can:

a. **Analyze and interpret patterns of change in fossils to provide evidence of the history of life on Earth.**

b. **Construct explanations for the anatomical similarities and differences between fossils of once-living organisms and organisms living today.** [Clarification Statement: Students should use the record of evolutionary descent between ancient and modern-day organisms.]

c. **Develop explanations for why most individual organisms, as well as some entire species of organisms, that lived in the past were never fossilized.** [Assessment Boundary: The process of fossilization is not treated in any detail within the life sciences but addressed in the Earth sciences.]

d. **Recognize and compare patterns in the embryological development across different species to identify relationships not evident in the fully formed anatomy.** [Assessment Boundary: Limited to general characteristics of embryological development among species.]

e. **Communicate explanations for how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment which tends to increase these traits in the population.**

f. **Use mathematical models to explain how natural selection over many generations results in changes within species in response to environmental conditions that increase or decrease certain traits in a population.** [Clarification Statement: Population data for organisms over time showing trends in numbers of individuals with specific traits.] [Assessment Boundary: Data should be provided to students.]

g. **Obtain and evaluate information about how two populations of the same species in different environments have evolved to become separate 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

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Distinguish between causal and correlational relationships. (a)
- Use graphical displays to analyze data in order to identify linear and nonlinear relationships. (d)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical concepts such as ratios, averages, basic probability, and simple functions, including linear relationships to analyze data. (f)

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 scientific knowledge, principles, and theories.

- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (b)
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (c)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluating the merit and validity of ideas and methods.

- Generate and communicate ideas using scientific language and reasoning. (e)
- Gather, read, and explain information from appropriate sources and evaluate the credibility of the publication, authors, possible bias of the source, and methods used. (g)

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Fossils are mineral replacements, preserved remains, or traces of organisms that lived in the past. Thousands of layers of sedimentary rock not only provide evidence of the history of the Earth itself but also of changes in organisms whose fossil remains have been found in those layers. (a)
- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. Because of the conditions necessary for their preservation, not all types of organisms that existed in the past have left fossils that can be retrieved. (c)
- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (b)
- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (d)

LS4.B: Natural Selection

- Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population, and the suppression of others. (e),(f)

LS4.C: Adaptation

- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. (g)
- Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (f)
- In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to be separate species. (g)

Crosscutting Concepts

Patterns
Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (a),(b),(d)

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (c),(e),(f)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (g)

Connections to other topics in this grade-level: **MS.ESS-HE**

Articulation across grade-levels: **3.EIO, 3.SFS, 4.PSE, 4.LCT, HS.LS-NSE, HS.LS-IRE, HS.PS-NP**

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

ELA –

SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.6 Attend to precision.
MP.4 Model with mathematics.
5.OA Analyze patterns and relationships.
6.EE Apply and extend previous understandings of arithmetic to algebraic expressions.
Reason about and solve one-variable equations and inequalities.
7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.LS-GDRO Growth, Development, and Reproduction of Organisms

MS.LS-GDRO Growth, Development, and Reproduction of Organisms

dents who demonstrate understanding can:

a. **Use evidence to support an explanation of how environmental and genetic factors affect the growth of organisms.** [Clarification Statement: The emphasis is on the impact of factors in terms of cause and effect, not the mechanism (e.g., abundant food leads to more significant growth, offspring of large breeds of dogs are larger than the offspring of small dogs).]

b. **Investigate and present evidence that plants continue to grow throughout their life through the production of new plant matter via photosynthesis.** [Assessment Boundary: Reproduction is not treated in any detail here, for more specifics of grade level see DCI LS3.A.]

c. **Use models to construct an explanation of how the genetic contribution from each parent through sexual reproduction results in variation in offspring and how asexual reproduction results in offspring with identical genetic information.** [Assessment Boundary: The emphasis is on the impact of gene transmission in reproduction, not the mechanism of the gene interactions.]

d. **Plan and conduct investigations to gather evidence for the relationship among specialized plant structures, specific animal behaviors, and the successful reproduction of the plant.** [Clarification Statement: Examples of evidence of successful reproduction of plants could include placement of stamen and bees gathering nectar, hard shells on pine nuts and squirrels burying nuts.]

e. **Use empirical evidence to support an argument for how characteristic animal behaviors affect the probability of successful reproduction.** [Clarification Statement: Examples of animal behaviors could include birds building nests to protect young, brown trout spawning in late fall when predators are less active.]

f. **Provide explanations of how changes (mutations) to genes, which are located on chromosomes, affect specific inherited traits resulting in harmful, beneficial, or neutral effects.**

g. **Provide an explanation for the relationship among changes (mutations) to genes, changes to the formation of proteins, and the effect on the structure and function of the organism and thereby traits.**

h. **Communicate explanations of ways technologies enable humans to influence the inheritance of certain traits in plants and animals.** [Clarification Statement: Examples of human influence could be breeds of cattle for various purposes, disease resistant crops, genetically modified organisms.]

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 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Modify models—based on their limitations—to increase detail or clarity, or to explore what will happen if a component is changed. (c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (b)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (b)

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 scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (a),(d),(f),(g)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (e)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluating the merit and validity of ideas and methods.
- Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions, and competing information. (h)

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (c)
- Animals engage in characteristic behaviors that increase the odds of reproduction. (e)
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (such as attractively colored flowers) for reproduction. (d)
- Plant growth can continue throughout the plant's life through production of plant matter in photosynthesis. (b)
- Genetic factors as well as local conditions affect the size of the adult plant. The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range. (a)

LS3.A: Inheritance of Traits
- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. (c),(f)
- Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual (e.g., human skin color results from the actions of proteins that control the production of the pigment melanin). (c)
- Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. (f),(g)
- Sexual reproduction provides for transmission of genetic information to offspring through egg and sperm cells. These cells, which contain only one chromosome of each parent's chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent's chromosome pair (forming a new chromosome pair). Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited or (more rarely) from mutations. (c)

LS3.B: Variation of Traits
- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. (c)
- In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism. (f)

LS4.B: Natural Selection
- In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. (h)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(b),(c),(d),(e),(f)

Structure and Function
Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (d),(g)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies from region to region and over time. (h)

MS.LS-GDRO Growth, Development, and Reproduction of Organisms *(continued)*
Connections to other topics in this grade-level: **MS.PS-CR**
Articulation across grade-levels: **4.LCT, HS.LS-IVT, HS.LS-NSE**
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases] *ELA –* **W.6.1** Write arguments to support claims with clear reasons and relevant evidence. **W.7.1** Write arguments to support claims with clear reasons and relevant evidence. **RI.6.7** Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue. **WHST.7** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. *Mathematics –* **MP.2** Reason abstractly and quantitatively. **MP.3** Construct viable arguments and critique the reasoning of others. **5.OA** Analyze patterns and relationships. **6.EE** Represent and analyze quantitative relationships between dependent and independent variables. **7.SP.1,2** Use random sampling to draw inferences about a population

MS.ESS-SS Space Systems

dents who demonstrate understanding can:

a. **Construct explanations for the occurrences of day/night cycles, seasons, tides, eclipses, and lunar phases based on patterns of the observed motions of celestial bodies.** [Assessment Boundary: Kepler's Laws of orbital motion are not used as the basis for evidence at this level.]

b. **Obtain, evaluate, and communicate information about the expansion and scale of the universe to support the Big Bang theory.** [Clarification Statement: Evidence should include qualitative discussions of the cosmic background radiation, the motions of galaxies away from each other, and the resulting prevalence of hydrogen and helium in the universe.]

c. **Construct and use models to describe the location of Earth with respect to the size and structure of the solar system, Milky Way Galaxy, and universe.** [Assessment Boundary: Mathematical models are not expected; use AU for Solar System scale; use light years for universal scale.]

d. **Use models to support explanations of the composition, structure, and formation of the solar system from a disk of dust and gas drawn together by gravity.**

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 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (c),(d)

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 scientific knowledge, principles, and theories.
- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (a)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluate the merit and validity of ideas and methods.
- Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions, and competing information. (b)

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (a)
- The universe began with a period of extreme and rapid expansion known as the Big Bang. Nearly all observable matter in the universe is hydrogen or helium, which formed in the first minutes after the Big Bang. (b)
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (c)

ESS1.B: Earth and the Solar System
- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. This system appears to have formed from a disk of dust and gas, drawn together by gravity. (d)
- This model of the solar system can explain tides, eclipses of the sun and the moon, and the apparent motions of the planets in the sky relative to the stars. (a)
- Earth's spin axis is fixed in direction (in the short-term) but tilted relative to its orbit around the sun; the differential intensity of sunlight on different areas of Earth over the year is a result of that tilt, as are the seasons that result. (a)

PS2.C: Stability and Instability in Physical Systems
- A system can be changing but have a stable repeating cycle of changes; such observed regular patterns allow predictions about the system's future (e.g., Earth orbiting the sun). (a)

Crosscutting Concepts

Patterns
Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (a),(d)

Scale, Proportion, and Quantity
Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (b)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (c)

Connections to other DCIs in this grade-level: **MS.LS-GDRO, MS.PS-FM, MS.PS-IF, MS.PS-E**

Articulation to DCIs across grade-levels: **1.PC, 5.SSS, HS.ESS-SS**

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

ELA –

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.
W.6.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
W.7.1 Write arguments to support claims with clear reasons and relevant evidence.
W.7.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
W.8.1 Write arguments to support claims with clear reasons and relevant evidence.
W.8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.4 Model with mathematics
8.F Use functions to model relationships between quantities

MS.ESS-HE The History of Earth

MS.ESS-HE The History of Earth

Students who demonstrate understanding can:

a. **Construct explanations for patterns in geologic evidence to determine the relative ages of a sequence of events that have occurred in Earth's past.** [Clarification Statement: Evidence can be field evidence or representations (e.g., model of geologic cross-sections). Events may include sedimentary layering, fossilization, folding, faulting, igneous intrusion, and/or erosion.]

b. **Use models of the geologic time scale in order to organize major events in Earth's history.** [Clarification Statement: Models may be temporal (e.g., clock) or spatial (e.g., football field).] [Assessment Boundary: Memorization of specific periods or epochs of the geologic timescale is not intended.]

c. **Construct explanations from evidence for how different geologic processes shape Earth's evolution over widely varying scales of space and time.** [Clarification Statement: Chemical erosion of a mountain occurs at molecular scales while mountain building can occur through large-scale tectonic processes; meteor impacts are nearly instantaneous, mountain building can take many millions of years. It is appropriate to use regional geographical features familiar to students.]

d. **Use empirical evidence from the rock and fossil records to investigate how past geologic events have caused major extinctions of life forms on Earth and how these extinctions have subsequently allowed other life forms to flourish.**

e. **Use models of the geosphere and biosphere that highlight system interactions to explain how the geosphere and biosphere coevolve over geologic time.** [Assessment Boundary: Use examples of weathering and erosion of land surfaces, composition of soils and atmosphere, and distribution of water in the hydrosphere.]

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 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (b),(e)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis (a possible explanation that predicts a particular and stable outcome) based on a model or theory. (d)

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 scientific knowledge, principles, and theories.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (a)
- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (c)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth
- The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Major historical events include the formation of mountain chains and ocean basins, evolution and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and the development of watersheds and rivers through glaciation and water erosion. (b)
- Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (a)

ESS2.A: Earth's Materials and Systems
- Earth's systems interact over scales that range from microscopic to global in size, and operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (c)

ESS2.E: Biogeology
- The evolution of life is shaped by Earth's varying geologic conditions. Sudden changes in these conditions (e.g., meteor impacts or major volcanic eruptions) have caused mass extinctions in Earth's past. However, these changes, as well as more gradual ones, have also allowed other existing or new life forms to flourish. (d)
- Organisms continually evolve to new and often more complex forms as they adapt to new environments. (e)
- The evolution and proliferation of living things over geologic time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere. (e)

Crosscutting Concepts

Scale, Proportion, and Quantity
Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (a)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (b)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (c),(d),(e)

Connections to other DCIs in this grade-level: **MS.LS-NSA, MS.LS-IRE**

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

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

ELA –

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

W.6.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

SL.6.3 Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.

W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

W.7.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

SL.7.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

W.8.1 Write arguments to support claims with clear reasons and relevant evidence.

W.8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

SL.8.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.3 Reason abstractly and quantitatively

MP.4 Model with mathematics.

.F Use functions to model relationships between quantities

.SP Investigate patterns of association in bivariate data

MS.ESS-EIP Earth's Interior Processes

MS.ESS-EIP Earth's Interior Processes

dents who demonstrate understanding can:

a. **Use models to explain how the flow of energy drives a cycling of matter between Earth's surface and deep interior.** [Assessment Boundary: The thermodynamic processes that drive convection are not required, only a description of those motions. Explanations should include mid-ocean ridges and ocean trenches.]

b. **Develop and use models of ancient land and ocean basin patterns to explain past plate motions.** [Assessment Boundary: Explanations should be based on fossil evidence, evidence from rock formations, continent shapes, and seafloor structures.]

c. **Use representations of current plate motions, based on data from modern techniques like GPS, to predict future continent locations.** [Clarification Statement: Representations may include maps.]

d. **Plan and carry out investigations that demonstrate the chemical and physical processes that form rocks and cycle Earth materials.** [Assessment Boundary: Students should use various materials to replicate, simulate, and demonstrate the processes of crystallization, heating and cooling, weathering, deformation, and sedimentation involved. Investigations should focus on connecting, correlating, and identifying parts of the rock cycle.]

e. **Construct explanations for how the uneven distribution of Earth's mineral and energy resources, which are limited and often non-renewable, are a result of past and current geologic processes, including plate motions.**

f. **Analyze and interpret data sets to describe the history of natural hazards in a region to identify the patterns of hazards that allow for forecasts of the locations and likelihood of future events.** [Assessment Boundary: Hazards are limited to those resulting from Earth's interior processes (e.g., volcanoes, earthquakes, tsunamis).]

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 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a),(b),(c)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (d)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
- Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships
- Distinguish between causal and correlational relationships. (f)

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 scientific knowledge, principles, and theories.
- Base explanations on evidence and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (e)

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth
- Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (a)

ESS2.A: Earth Materials and Systems
- Earth's internal processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from Earth's hot interior. The flow of energy and cycling of matter produce chemical and physical changes in Earth's interior materials and living organisms. (a)
- Solid rocks can be formed by the cooling of molten rock, the accumulation and consolidation of sediments, or the alteration of older rocks by heat, pressure, and fluids. (d)

ESS2.B: Plate Tectonics and Large-Scale System Interactions
- The top part of the mantle, along with the crust, forms structures known as tectonic plates. (b),(c)
- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart. (b)

ESS3.A: Natural Resources
- Humans depend on Earth's interior for many different resources. Mineral and energy resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (e)

ESS3.B: Natural Hazards
- Some natural hazards, such as volcanic eruptions, are preceded by phenomena that allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. However, mapping the history of natural hazards in a region and developing an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (f)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (b),(c),(d)

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (a),(e)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology, on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (f)

Connections to other DCIs in this grade-level: **MS.ESS-ESP, MS.PS-IF, MS.PS-E, MS.PS-CR, MS.PS-SPM**

Articulation to DCIs across grade-levels: **K.WEA, 2.ECS, 3.WCI, 4.PSE, 5.ESI, HS.ESS-ES, HS.ESS-HS**

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

ELA –

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
W.6.1 Write arguments to support claims with clear reasons and relevant evidence.
W.7.1 Write arguments to support claims with clear reasons and relevant evidence.
SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
W.8.1 Write arguments to support claims with clear reasons and relevant evidence.
SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.3 Reason abstractly and quantitatively
MP.4 Model with mathematics.
[illegible] Use functions to model relationships between quantities
P Investigate patterns of association in bivariate data

MS.ESS-ESP Earth's Surface Processes

MS.ESS-ESP Earth's Surface Processes

Students who demonstrate understanding can:

a. Use models to explain how weathering, erosion, and deposition of Earth materials, by the movement of water, shape landscapes and create underground formations. [Clarification Statement: Models may include maps.]

b. Model multiple pathways for the cycling of water through the atmosphere, geosphere, and hydrosphere as it changes phase and moves in response to energy from the sun and the force of gravity. [Assessment Boundary: Heat of vaporization and heat of condensation are not to be addressed.]

c. Plan and conduct investigations to explain how temperature and salinity cause changes in density which affect the separation and movement of water masses within the ocean. [Assessment Boundary: Complex system interactions such as the Coriolis Effect are not required.]

d. Plan and carry out investigations of the variables that affect how water causes the erosion, transportation, and deposition of surface and subsurface materials as evidence of how matter cycles through Earth's systems.

e. Apply scientific knowledge to design engineered solutions to natural hazards that result from surface geologic and hydrologic processes. [Clarification Statement: Examples of natural hazards are flooding, avalanches, and landslides. Direct methods engineers use to control flooding include building artificial levees and dams.]

f. Generate and revise causal explanations for how physical and chemical interactions among rocks, sediments, water, air, and organisms contribute to the weathering and erosion of rocks and the formation of soil.

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 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a),(b)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables, and controls. (c)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (d)

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 scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (f)
- Apply scientific knowledge to explain real-world examples or events and solve design problems. (e)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems

- Earth's surface processes are the result of energy flowing and matter cycling within and among the planet's surface systems. This energy is derived from electromagnetic radiation from the sun. This flow of energy and cycling of matter produce chemical and physical changes in Earth's surface materials and living organisms. (b),(d)
- Physical and chemical interactions among rocks, sediments, water, air, and plants and animals produce soil. (f)

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

- Water continually cycles among the land, ocean, and atmosphere via transpiration, evaporation, condensation, precipitation, and the downhill runoff on land. Global movements of water and changes in its chemical phase are driven by sunlight and gravity. (b)
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. (c)
- Water's movements both on the land and underground cause weathering and erosion, which change the land's surface features and create underground formations. (a)

ESS3.B: Natural Hazards

- Surface-related geologic processes create natural resources needed by humans and cause natural hazards that pose challenges to human society (e.g., landslides, coastal erosion). (e)

Crosscutting Concepts

Cause and Effect

Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (c),(d),(f)

Systems and System Models

Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (a),(b)

Connections to Engineering, Technology, and Applications of Science

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

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (e)

Connections to other DCIs in this grade-level: **MS.ESS-EIP, MS.LS-MEOE MS.PS-IF, MS.PS-E, MS.PS-CR, MS.PS-WER, MS.PS-SPM**

Articulation to DCIs across grade-levels: **K.WEA, 3.WCI, 4.PSE, 5.ESI, HS.ESS-ES, HS.ESS-HS**

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

ELA –

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

W.8.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.3 Reason abstractly and quantitatively

MP.4 Model with mathematics.

7.RP Analyze proportional relationships and use them to solve real-world and mathematical problems

8.F Use functions to model relationships between quantities

MS.ESS-WC Weather and Climate Systems

MS.ESS-WC Weather and Climate Systems

.udents who demonstrate understanding can:

a. **Generate and revise causal explanations given specific temperature and precipitation data sets at different geographic locations to answer questions about interactions that influence weather.** [Clarification Statement: Factors that interact and influence weather should include sunlight, ocean, atmosphere, ice, landforms and living things.] [Assessment Boundary: Students consider interactions between only two variables at a time.]

b. **Construct models to describe and explain how circulation in the atmosphere and ocean results from unequal heating of Earth's surface and is influenced by latitude, altitude, geography, and Earth's rotation.** [Clarification Statement: Atmospheric and oceanic circulation may include Hadley cells, the Gulf Stream, and the prevailing westerlies and trade winds.] [Assessment Boundary: Students do not need to explain the mechanism causing the Coriolis effect.]

c. **Use mathematics to analyze weather data and forecasts to identify patterns and variations that cause weather forecasts to be issued in terms of probabilities.** [Clarification Statement: Averages and basic probability should be used to analyze weather data.]

d. **Construct explanations, from models of oceanic and atmospheric circulation, for the development of local and regional climates.** [Assessment Boundary: Students should construct explanations for their own local climate.]

e. **Use models of Earth's atmosphere and surface to explain how energy from the sun is absorbed and retained by various greenhouse gases in Earth's atmosphere, thereby regulating Earth's average surface temperature and keeping Earth habitable.** [Assessment Boundary: Explanations should include an understanding that energy can take different forms and can be tracked as it moves through Earth's systems. Students do not have to explain the differing wavelengths of radiation received and reemitted from Earth's surface. Amount of energy absorbed by different reservoirs is not assessed at this level.]

f. **Construct a model to track and explain the inputs, outputs, pathways, and storage of carbon among the geosphere, biosphere, hydrosphere, and atmosphere.** [Assessment Boundary: Details of biogeochemical reactions involving carbon and actual amounts of reactants and products are not assessed at this level.]

g. **Use argumentation to evaluate the competing demands for various human uses of fresh water and biosphere resources.** [Assessment Boundary: Arguments should take into account the uneven distribution of the resources and the natural limits to their availability.]

h. **Use maps and other visualizations to analyze large data sets that illustrate the frequency, magnitude, and resulting damage from severe weather events in order to assess the likelihood and severity of future events.**

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 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (b),(e),(f)

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigation, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships. (h)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical concepts such as ratios, averages, basic probability, and simple functions, including linear relationships, to analyze data. (c)

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 scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (a)
- Construct explanations from models or representations. (d)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (g)

Disciplinary Core Ideas

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

- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. (a),(b),(d)

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (a),(b)
- Because these patterns are so complex, weather can only be predicted probabilistically. (c),(e)
- The ocean and land exert major influences on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it via oceanic and atmospheric circulation. The patterns of differential heating, together with Earth's rotation and the configuration of continents and oceans, control the large-scale patterns of oceanic and atmospheric circulation. (a),(b),(d)
- Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping Earth habitable. (e)

ESS2.E: Biogeology

- Organisms ranging from bacteria to human beings are a major driver of the global carbon cycle, and they influence global climate by modifying the chemical makeup of the atmosphere. (e),(f)

ESS3.A: Natural Resources

- Humans depend on Earth's ocean, atmosphere, and biosphere for many different resources. Fresh water and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of weather-and climate-related processes. (g)

ESS3.B: Natural Hazards

- Severe weather events (e.g., hurricanes, floods, forest fires) are often preceded by observable phenomena that allow for reliable predictions. Constant monitoring of weather hazards in a region and the development of an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (h)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(b),(c),(d),(h)

Energy and Matter
Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (e),(f)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (g)

MS.ESS-WC Weather and Climate Systems

MS.ESS-WC Weather and Climate Systems	
Connections to other DCIs in this grade-level: **MS.LS-MEOE, MS.PS-IF, MS.PS-E, MS.PS-WER**	
Articulation to DCIs across grade-levels: **K.WEA, 3.WCL, 4.PSE, 4.E, HS.ESS-CC, HS.ESS-HS**	
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]	
ELA –	
WHST.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
W.6.1	Write arguments to support claims with clear reasons and relevant evidence.
W.7.1	Write arguments to support claims with clear reasons and relevant evidence.
SL.7.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
W.8.1	Write arguments to support claims with clear reasons and relevant evidence.
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
Mathematics –	
MP.3	Reason abstractly and quantitatively
MP.4	Model with mathematics.
7.RP	Analyze proportional relationships and use them to solve real-world and mathematical problems

MS.ESS-HI Human Impacts

MS.ESS-HI Human Impacts

dents who demonstrate understanding can:

a. **Use system models and representations to explain how human activities significantly impact: (1) the geosphere, (2) the hydrosphere, (3) the atmosphere, (4) the biosphere, and (5) global temperatures.** [Clarifying Statement: System models and representations include diagrams, charts, and maps. Examples of human impact are changes in land use and resource development (geosphere); water pollution and urbanization (hydrosphere); air pollution in the form of gases, aerosols, and particulates (atmosphere); changes to natural environments (biosphere); release of greenhouse gases (global temperatures).]

b. **Generate and revise qualitative explanations from data for the impacts on Earth's systems that result from increases in human population and rates of consumption.** [Assessment Boundary: Students should be provided with modified regional databases on human populations and rates of consumption. "Impacts" include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change.]

c. **Design engineering solutions for stabilizing changes to communities by: (1) using water efficiently, (2) minimizing human impacts on environments and local landscapes by reducing pollution, and (3) reducing the release of greenhouse gases.**

d. **Ask questions to refine and develop an explanation for the way technological monitoring of Earth's systems can provide the means of informing the public of ways to modify human impacts on Earth's systems.**

e. **Use empirical evidence to evaluate technologies that utilize renewable energy resources.** [Assessment Boundary: Students will evaluate these technologies based on their cost, benefit, sustainability, and environmental impacts.]

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 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions and explanatory models.

- Ask questions to refine a model, an explanation, or an engineering problem. (d)

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (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 scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (b)
- Apply scientific knowledge to explain real-world examples or events and solve design problems. (c)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (e)

Disciplinary Core Ideas

ESS3.C: Human Impacts on Earth Systems

- Humans have become one of the most significant agents of change in the near-surface Earth system. Human activities have significantly altered the biosphere, geosphere, hydrosphere, and atmosphere. (a)
- As human populations and per-capita consumption of natural resources increase, so do the impacts on Earth's systems unless the activities and technologies involved are engineered otherwise. (b),(c)
- Continued monitoring of the changes to Earth's surface provides a deeper understanding of the way in which human activities are impacting Earth's systems, providing the basis for social policies and regulations that can reduce these impacts. (d)

ESS3.D: Global Climate Change

- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature ("global warming"). (a)
- Reducing the amount of greenhouse gases released into the atmosphere can reduce the degree to which global temperatures will increase. (c)
- Renewable energy resources and the technologies to exploit them are being rapidly developed. (e)

Crosscutting Concepts

Systems and System Models

Systems may interact with other systems; they may have sub-systems and be part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (a)

Stability and Change

Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (c)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. Science and technology drive each other forward. (d)

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

All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (b),(e)

Connections to other DCIs in this grade-level: **MS.LS-NSA, MS.LS-IRE, MS.PS-E, MS.PS-WER, MS.PS-SPM**

Articulation to DCIs across grade-levels: **K.OTE, 5.ESI, HS.ESS-CC, HS.ESS-HS**

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

ELA –

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

W.8.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.3 Reason abstractly and quantitatively

MP.4 Model with mathematics

Use random sampling to draw inferences about a population; Draw informal comparative inferences about two populations

MS.PS-SPM Structure and Properties of Matter

MS.PS-SPM Structure and Properties of Matter

Students who demonstrate understanding can:

a. Construct and use models to explain that atoms combine to form new substances of varying complexity in terms of the number of atoms and repeating subunits. [Clarification Statement: Examples of atoms combining can include Hydrogen (H_2) and Oxygen (O_2) combining to form hydrogen peroxide (H_2O_2) or water (H_2O).] [Assessment Boundary: Valence electrons and bonding energy are not addressed.]

b. Plan investigations to generate evidence supporting the claim that one pure substance can be distinguished from another based on characteristic properties. [Clarification Statement: Properties of substances can include melting and boiling points, density, solubility, reactivity, flammability, and phase.]

c. Use a simulation or mechanical model to determine the effect on the temperature and motion of atoms and molecules of different substances when thermal energy is added to or removed from the substance. [Assessment Boundary: Quantification of the model or use of mathematical formulas are not intended.]

d. Construct an argument that explains the effect of adding or removing thermal energy to a pure substance in different phases and during a phase change in terms of atomic and molecular motion. [Assessment Boundary: The use of mathematical formulas is not 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

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a),(c)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables, and controls. (b)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (b)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an explanation for a phenomenon or a solution to a problem. (d)

Disciplinary Core Ideas

PS1.A: Structure and Properties of Matter

- All substances are made from some 100 different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (a)
- Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (b)
- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (d)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (c),(d)
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (a)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (c),(d)

PS3.A: Definitions of Energy

- The term "heat" as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). (c),(d)
- Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (c),(d)

Crosscutting Concepts

Patterns

Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (a)

Cause and Effect

Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (c),(d)

Structure and Function

Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (b)

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

Articulation of DCIs across grade-levels: **3.IF, 5.SPM, HS.PS.SPM, HS.PS-NP, HS.PS-E**

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

ELA –

W.5.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

SL.5.4 Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

WHST.6-8.1 Write arguments focused on discipline-specific content.

RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Mathematics –

MP.4 Model with mathematics.

MP.8 Look for and express regularity in repeated reasoning.

6.SP Develop understanding of statistical variability

Summarize and describe distributions

MS.PS-CR Chemical Reactions

^S.PS-CR Chemical Reactions

ɟents who demonstrate understanding can:

a. Develop representations showing how atoms regroup during chemical reactions to account for the conservation of mass. [Assessment Boundary: Representations should not involve bonding energy or valence electrons. Balancing equations are also not employed here.]

b. Generate and revise explanations from the comparison of the physical and chemical properties of reacting substances to the properties of new substances produced through chemical reactions to show that new properties have emerged. [Assessment Boundary: Comparison and analysis should not involve statistical techniques.]

c. Construct explanations of energy being released or absorbed when simpler molecules are combined into complex molecules or complex molecules are broken down to simpler molecules. [Clarification Statement: Simple molecules can include H_2O and CO_2, and complex molecules can include $C_6H_{12}O_6$ in photosynthesis.] [Assessment Boundary: Further details of the photosynthesis process are not addressed.]

d. Develop models to represent the movement of matter and energy in the cycling of carbon. [Clarification Statement: Examples of the movement of matter and energy could include the cycling from carbon in the atmosphere to carbon in living things.] [Assessment Boundary: Further details of the photosynthesis process are not addressed.]

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 6–8 builds on K–5 and progresses to developing, using, and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)
- Pose models to describe mechanisms at unobservable scales. (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 scientific knowledge, principles, and ...ries.

- ...onstruct explanations for either qualitative or quantitative relationships between variables. (b)
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (c)

Disciplinary Core Ideas

PS1.B: Chemical Reactions

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (a),(b)
- The total number of each type of atom is conserved, and thus the mass does not change. (a),(c)
- Some chemical reactions release energy, others store energy. (c)

PS3.D: Energy in Chemical Processes and Everyday Life

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (c),(d)
- Both the burning of fuel and cellular digestion in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (d)

Crosscutting Concepts

Patterns

Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (b)

- [Clarification Statement for b: Comparing properties is a search for patterns; finding a change in pattern indicates a new substance.]

Energy and Matter

Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (a),(d)

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (c)

Connections to other DCIs in this grade level: **MS.LS-SFIP, MS.LS-GDRO, MS.LS-MEOE, MS.ESS-WC, MS.ESS-ESP**

Articulation to DCIs across grade-levels: **5.SPM, HS.PS-CR, HS.PS-E, HS.LS-MEOE**

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

ELA –

RI.6.7 Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.

W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

W.6.8 Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.

W.7.8 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.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

MP.7 Look for and make use of structure.

MP.8 Look for and express regularity in repeated reasoning.

6.SP Develop understanding of statistical variability.

6.EE Represent and analyze quantitative relationships between dependent and independent variables.

7.SP.3 Draw informal comparative inferences about two populations.

MS.PS-E Energy

MS.PS-E Energy

Students who demonstrate understanding can:

a. **Construct an explanation of the proportional relationship pattern between the kinetic energy of an object and its mass and speed.** [Assessment Boundary: Not intended to solely require use of $KE=1/2mv^2$—the explanation requires a qualitative description of the relationship and patterns.]

b. **Use representations of potential energy to construct an explanation of how much energy an object has when it's in different positions in an electrical, gravitational, and magnetic field.** [Clarification Statement: Examples of objects in different field positions include a roller coaster cart at varying positions on a hill, objects at varying heights on shelves, an iron nail being moved closer to a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair.] [Assessment Boundary: Qualitative, not quantitative.]

c. **Plan and carry out investigations to show that in some chemical reactions energy is released or absorbed.** [Clarification Statement: Examples of chemical reactions can include baking soda reacting with vinegar, and calcium chloride reacting with baking soda.] [Assessment Boundary: Qualitative, not quantitative.]

d. **Use and/or construct models to communicate the means by which thermal energy is transferred during conduction, convection, and radiation.** [Clarification Statement: Examples of models can include a diagram depicting thermal energy transfer through a pan to its handle or warmer water in a pan rising as cooler water sinks; and a model using a heat lamp for the sun and a globe for the earth.]

e. **Collect data and generate evidence to examine the relationship between the change in the temperature of a sample and the nature of the matter, the size of the sample, and the environment.** [Clarification Statement: Examples of data collection could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature.]

f. **Compare, evaluate, and design a device that maximizes or minimizes thermal energy transfer, and defend the selection of materials chosen to construct the device.** [Assessment Boundary: Excludes semiconductors and heat sinks.]

g. **Design and evaluate solutions that minimize and/or maximize friction and energy transfer in everyday machines.** [Clarification Statement: Solutions can include use of oil as a lubricant on a skateboard, bicycle, or in a lawnmower engine, and wax on skis. Energy transfer can include the transfer of energy from motion to thermal energy due to friction. Everyday machines can include skateboards, bicycles, lawnmowers, skis, and toy cars.]

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 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.
- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (d)

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (c)
- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (e)

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 scientific knowledge, principles, and theories.
- Use qualitative and quantitative relationships between variables to construct explanations for phenomena. (a)
- Construct explanations from models or representations. (b)
- Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. (f),(g)

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.
- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (f)

Disciplinary Core Ideas

PS3.A: Definitions of Energy
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (a)
- A system of objects may also contain stored (potential) energy, depending on their relative positions. For example, energy is stored—in gravitational interaction with Earth—when an object is raised, and energy is released when the object falls or is lowered. Energy is also stored in the electric fields between charged particles and the magnetic fields between magnets, and it changes when these objects are moved relative to one another. (b)
- Stored energy is decreased in some chemical reactions and increased in others. (c)
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. (d),(e)

PS3.B: Conservation of Energy and Energy Transfer
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. For example, the friction that causes a moving object to stop also results in an increase in the thermal energy in both surfaces; eventually heat energy is transferred to the surrounding environment as the surfaces cool. Similarly, to make an object start moving or to keep it moving when friction forces transfer energy away from it, energy must be provided from, say, chemical (e.g., burning fuel) or electrical (e.g., an electric motor and battery) processes. (f),(g)
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. (e)
- Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation. (d)

PS3.D: Energy in Chemical Processes and Everyday Life
- Machines can be made more efficient, that is, require less fuel input to perform a given task, by reducing friction between their moving parts and through aerodynamic design. Friction increases energy transfer to the surrounding environment by heating the affected materials. (f),(g)

Crosscutting Concepts

Scale, Proportion, and Quantity
Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (a),(b)

Energy and Matter
Matter is conserved because atoms are conserved in physical and chemical processes. Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter. (c)

Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion). The transfer of energy can be tracked as energy flows through a designed or natural system. (d),(e)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region. (f),(g)

PS-E Energy *(continued)*

Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.LS-MEOE, MS.ETS-ED**

Articulation to DCIs across grade-levels: **4.E, HS.PS-E, HS.PS-FE**

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

ELA –

W.6.1 Write arguments to support claims with clear reasons and relevant evidence
W.7.1 Write arguments to support claims with clear reasons and relevant evidence
W.8.1 Write arguments to support claims with clear reasons and relevant evidence
WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
5.MD Represent and interpret data.
6.RP Understand ratio concepts and use ratio reasoning to solve problems.
6.EE Apply and extend previous understandings of arithmetic to algebraic expressions
Represent and analyze quantitative relationships between dependent and independent variables.
7.RP Analyze proportional relationship and use them to solve real-world and mathematical problems.
7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-FM Forces and Motion

MS.PS-FM Forces and Motion

Students who demonstrate understanding can:

a. **Formulate questions arising from investigating how an observer's frame of reference and the choice of units influence how the motion and position of an object can be described and communicated to others.** [Clarification Statement: Examples of different reference frames or choices of units are: A moving observer versus a stationary observer; observers facing different directions; and cm for short distances but km for long distances.] [Assessment Boundary: Observations are made at the macroscopic scale only.]

b. **Communicate observations and information graphically and mathematically to represent how an object's relative position, velocity, and direction of motion are affected by forces acting on the object.** [Assessment Boundary: Restricted to motion in one dimension. The use of vectors is not an expectation.]

c. **Collect data to generate evidence supporting Newton's Third Law, which states that when two objects interact they exert equal and opposite forces on each other.** [Clarification Statement: Examples of interacting objects can include a book resting on a table; and skaters facing one another with hands together, then pushing off of one another.] [Assessment Boundary: Restrict to vertical or horizontal interactions; interactions at angles requiring trigonometry is not an expectation.]

d. **Use mathematical concepts and observations to describe the proportional relationship between the acceleration of an object and the force applied upon the object, and the inversely proportional relationship of acceleration to its mass.** [Clarification Statement: Examples of these proportional and inversely proportional relationships can include a large truck requiring more force to slow down from a given speed to a stop than does a small truck and a ball pushed with a given force having a greater change in motion if the force is greater.] [Assessment Boundary: Simple formulas such as $F=ma$ and $w=mg$ could be used quantitatively; the use of trigonometry is not an expectation.]

e. **Plan and carry out investigations to identify the effect forces have on an object's shape and orientation.** [Clarification Statement: Effects of forces can include a small ball of mud or clay changing shape if force is added, such as pushing down on it or rolling it in your hands; and the orientation of a pencil on a desk changing if a force is applied to it.] [Assessment Boundary: When discussing an object's shape, description is purely qualitative. Simple formulas such as $s=d/t$ and $F=ma$ can be used quantitatively.]

f. **Analyze and interpret data to determine the cause and effect relationship between the motion of an object and the sum of the forces acting upon it.** [Clarification Statement: An example of the additive impact of forces on the motion of an object could include a situation in which one person may not be able to push a heavy object, but several people pushing and pulling in the same direction may move it.] [Assessment Boundary: Simple free-body diagrams are acceptable. The use of trigonometry is not an expectation. Assessments should include situations with both balanced and unbalanced forces.]

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 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions and explanatory models.

- Ask questions that arise from phenomena, models, or unexpected results. (a)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (c),(e)

Analyzing and Interpreting Data

Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Distinguish between causal and correlational relationships. (f)

Mathematical and Computational Thinking

Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical concepts such as ratios, averages, basic probability, and simple functions, including linear relationships, to analyze data. (d)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluate the merit and accuracy of ideas and methods.

- Communicate understanding of scientific information that is presented in different formats (e.g., verbally, graphically, textually, mathematically). (b)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (c)
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. (b),(f)
- The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (d)
- Forces on an object can also change its shape or orientation. (e)
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (a)

Crosscutting Concepts

Scale, Proportion, and Quantity

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (a)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (b),(d)

Stability and Change

Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (c),(e),(f)

PS-FM Forces and Motion

Connections to other DCIs in this grade-level: **MS.ESS-EIP, MS.ESS-SS**

Articulation to DCIs across grade-levels: **3.FI, HS.PS-FM, HS.PS-IF**

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

ELA –

RST.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

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

Mathematics –

MP 1 Make sense of problems and persevere in solving them

MP.2 Reason abstractly and quantitatively.

MP 4 Model with mathematics

MP.6 Attend to precision.

5.OA Analyze patterns and relationships.

6.RP Understand ratio concepts and use ratio reasoning to solve problems.

6.EE Apply and extend previous understandings of arithmetic to algebraic expressions.
Reason about and solve one-variable equations and inequalities.
Represent and analyze quantitative relationships between dependent and independent variables.

7.RP Analyze proportional relationships and use them to solve real-world and mathematical problems.

7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-IF Interactions of Forces

MS.PS-IF Interactions of Forces

Students who demonstrate understanding can:

a. Plan and carry out investigations to illustrate the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Investigations can include observing the electric force produced between two charged objects at different distances; and measuring the magnetic force produced by an electromagnet with a varying number of wire turns, number or size of dry cells, or size of iron core.] [Assessment Boundary: Qualitative, not quantitative; no assessment of Coulomb's law.]

b. Use a model or various representations to describe the relationship among gravitational force, the mass of the interacting objects, and the distance between them. [Clarification Statement: Examples of models and representations can include labeled diagrams of the relationship between Earth and man-made satellites, the International Space Station, and an airplane taking off.] [Assessment Boundary: Qualitative, not quantitative.]

c. Plan and carry out investigations to demonstrate that some forces act at a distance through fields. [Assessment Boundary: Fields included are limited to gravitational, electric, and magnetic. Determination of fields are qualitative not quantitative (e.g., forces between two human-scale objects are too small to measure without sensitive instrumentation.)]

d. Develop a simple model using given data that represents the relationship of gravitational interactions and the motion of objects in space. [Clarification Statement: Examples of simple models can include charts displaying mass, distance from the sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Use models to determine a relationship conceptually. Qualitative, not quantitative.]

e. Develop or modify models to demonstrate that systems can withstand small changes, relying on feedback mechanisms to maintain stability. [Assessment Boundary: Use models to determine a relationship conceptually, not quantitatively.]

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 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (b),(d)
- Pose models to describe mechanisms at unobservable scales. (b),(d)
- Modify models – based on their limitations – to increase detail or clarity, or to explore what will happen if a component is changed. (e)
- Use and construct models of simple systems with uncertain and less predictable factors. (e)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. (a),(c)

Disciplinary Core Ideas

PS2.B: Types of Interactions

- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (a)
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (d)
- Long-range gravitational interactions govern the evolution and maintenance of large-scale systems in space, such as galaxies or the solar system, and determine the patterns of motion within those structures. (b),(d)
- Forces that act at a distance (gravitational, electric, and magnetic) can be explained by force fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively). (c)

PS2.C: Stability and Instability in Physical Systems

- A stable system is one in which any small change results in forces that return the system to its prior state (e.g., a weight hanging from a string). (e)
- Many systems, both natural and engineered, rely on feedback mechanisms to maintain stability, but they can function only within a limited range of conditions. With no energy inputs, a system starting out in an unstable state will continue to change until it reaches a stable configuration (e.g., sand in an hourglass). (e)

Crosscutting Concepts

Cause and Effect

Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(b),(e)

Scale, Proportion, and Quantity

Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale. (c),(d)

Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (d)

Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.ESS-EIP, MS.ESS-ESP, MS.ESS-WC**

Articulation to DCIs across grade-levels: **3.FI, HS.PS-IF**

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

ELA –

RST.6.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP 1 Make sense of problems and persevere in solving them.
MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
MP.6 Attend to precision.
5.OA Analyze patterns and relationships.
6.EE Represent and analyze quantitative relationships between dependent and independent variables.
7.RP Analyze proportional relationship and use them to solve real-world and mathematical problems.
7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

MS.PS-WER Waves and Electromagnetic Radiation

MS.PS-WER Waves and Electromagnetic Radiation

Students who demonstrate understanding can:

a. **Use a drawing or physical representation of simple wave properties to explain brightness and color.** [Assessment Boundary: Qualitative, not quantitative. Restricted to the following wave properties: frequency, wavelength, and amplitude.]

b. **Plan and carry out investigations of sound traveling through various types of mediums and lack of medium to determine whether a medium is necessary for the transfer of sound waves.** [Clarification Statement: Examples of investigations examining a lack of medium could include using a vacuum bell jar.]

c. **Construct explanations of how waves are reflected, absorbed, or transmitted through an object, considering the material the object is made from and the frequency of the wave.** [Assessment Boundary: Qualitative application to light, sound, and seismic waves only.]

d. **Use empirical evidence to support the claim that light travels in straight lines except at surfaces between different transparent materials.** [Clarification Statement: Examples of surfaces between transparent materials can include air and water, and air and glass.] [Assessment Boundary: Only non-computational observations; alterations of the speed of waves is not assessed until high school.]

e. **Ask questions about certain properties of light that can be explained by a wave model of light.** [Clarification Statement: Examples of properties of light can include brightness, color, and the refracting of light in a prism.]

f. **Apply scientific knowledge to explain the application of waves in common communication designs.** [Clarification Statement: Examples of common communication designs can include cell phones, radios, remote controls, and Bluetooth.] [Assessment Boundary: Applications limited to ability to transmit, receive, and encode.]

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 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable questions and explanatory models.

- Ask questions that arise from phenomena, models, or unexpected results. (e)

Developing and Using Models

Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems.

- Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (a)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (b)

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 scientific knowledge, principles, and theories.

- Use qualitative and quantitative relationships between variables to construct explanations for phenomena. (c)
- Apply scientific knowledge to explain real-world examples or events. (f)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (d)

Disciplinary Core Ideas

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (a)
- A sound wave needs a medium through which it is transmitted. (b)
- Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet. (c)

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (c)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. Lenses and prisms are applications of this effect. (d)
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (prisms). However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (a),(e)

PS4.C: Information Technologies and Instrumentation

- Appropriately designed technologies (e.g., radio, television, cell phones, wired and wireless computer networks) make it possible to detect and interpret many types of signals that cannot be sensed directly. Designers of such devices must understand both the signal and its interactions with matter. (f)
- Many modern communication devices use digitized signals (sent as wave pulses) as a more reliable way to encode and transmit information. (f)

Crosscutting Concepts

Systems and System Models

Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (b),(e)

Structure and Function

Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural and designed structures/systems can be analyzed to determine how they function. Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (a),(c),(d),(f)

Connections to other DCIs in this grade-level: **MS.ESS-SS, MS.ESS-ESP, MS.ESS-EIP**

Articulation to DCIs across grade-levels: **3.SFS, 4.WAV, 5.SSS, HS.PS-W, HS.PS-ER, HS.PS-FM**

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

ELA –

SL.5.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

SL.6.3 Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not.

SL.7.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and the relevance and sufficiency of the evidence.

SL.8.3 Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

RST.6-8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Mathematics –

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

6 Attend to precision.

.c Represent and analyze quantitative relationships between dependent and independent variables.

MS-ETS-ED Engineering Design

'S-ETS-ED Engineering Design

.udents who demonstrate understanding can:

a. Evaluate ideas for solving an environmental problem to determine which designs best meet the criteria and constraints of the problem and take into account scientific principles and short and long-term consequences. [Clarification Statement: Students compare sand blasting, chemical solvent, and high heat for removing graffiti; evaluate different plans for solving problems due to invasive species.] [Assessment Boundary: A numerical weighting system may be used to evaluate designs, but not an advanced mathematical model.]

b. Develop a better design by combining characteristics of different solutions to arrive at a design that takes into account relevant scientific principles and better meets the needs of society. [Clarification Statement: For example, students develop a design for a highly energy efficient automobile by combining ideas from different car ads.] [Assessment Boundary: Limit arguments to qualitative characteristics.]

c. Compare different designs by building physical models and running them through the same kinds of tests, while systematically controlling variables and recording the results to determine which design performs best. [Clarification Statement: For example, students test different designs for a bridge by building and testing a model or compare different designs for a hydroponic farm by building and testing small scale models in the classroom.]

d. Use a computer simulation to test the effectiveness of a design under different operating conditions, or test what would happen if perameters of the model were changed, noting how the simulation may be limited in accurately modeling the real world. [Clarification Statement: Examples include simulating how a solar hot water system would function in different seasons or parts of the world and simulating the effects of different preventive actions in slowing the spread of disease during an epidemic.] [Assessment Boundary: Students should be given simulation software to use and not expected to create their own.]

e. Refine a design by conducting several rounds of tests, modifying the model after each test, to create the best possible design that meets the most important criteria. [Clarification Statement: For example, students refine the design of a model building to withstand an earthquake, strengthening failure points after each test, or refine the design of a water filtration system by adding physical and chemical components and retesting after each change.]

f. Communicate information about a proposed solution to a problem, including relevant scientific principles, how the design was developed, how it meets the criteria and constraints of the problem, and how it reduces the potential for negative consequences for society and the natural environment. [Clarification Statement: Students develop a poster, slide presentation, or oral design concept presentation.] [Assessment Boundary: Arguments should be limited to qualitative characteristics.]

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 6–8 builds on 3–5 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

- Plan and carry out investigations individually and collaboratively, identifying independent and dependent variables and controls. (c)
- Collect data and generate evidence to answer scientific questions or test design solutions. (c)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. (d)
- Use mathematical arguments to justify scientific conclusions and design solutions. (d)

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 scientific knowledge, principles, and theories.

- Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. (b),(e)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluate the merit and validity of ideas and methods.

- Generate and communicate ideas and methods using scientific language and reasoning. (a),(f)

Disciplinary Core Ideas

ETS1.A: Defining and Delimiting an Engineering Problem

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. (a)
- Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. (a)

ETS1.B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (e)
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (a)
- It is important to be able to communicate and explain solutions to others. (f)
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (b)
- Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. (d)
- Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback. (d)

ETS1.C: Optimizing the Design Solution

- Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. (c)
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process-that is, some of those characteristics may be incorporated into the new design. (c)
- This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (e)
- Once a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful. (f)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (a),(e)

Systems and System Models
Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study. (c),(d)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World
All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies from region to region and over time. (a),(b),(f)

MS-ETS-ED Engineering Design

M-ETS-ED Engineering Design** ***(continued)***

...ctions to other DCIs in this grade-level: **MS.ES-HI; MS.LS-GDRO; MS.PS-IF, MS.PS-E, MS.ETS-ETSS**

A...culation to DCIs across grade-levels: **1.SF, 2.ECS, 2.PP, 4.E, 4.PSE, 4.WAV, HS.ETS-ED**

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

ELA –

RST.6.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

W.7.1 Write arguments to support claims with clear reasons and relevant evidence.

W.8.1 Write arguments to support claims with clear reasons and relevant evidence.

WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP 1 Make sense of problems and persevere in solving them.

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

MP.6 Attend to precision.

6.EE Apply and extend previous understandings of arithmetic to algebraic expressions.
Represent and analyze quantitative relationships between dependent and independent variables.

7.RP Analyze proportional relationship and use them to solve real-world and mathematical problems.

7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

8.F Use functions to model relationships between quantities.

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

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

.udents who demonstrate understanding can:

a. **Provide examples to explain how advances in engineering have resulted in new tools and instruments for measurement, exploration, modeling, and computation that enable new scientific discoveries, which in turn lead to the development of entire industries and engineered systems.** [Clarification Statement: Examples include: microscopes enabled the germ theory of disease, which led to the development of antibiotics, stimulating growth of the pharmaceutical industry; discoveries in physics led to development of the integrated circuit, and computers, leading to many scientific breakthroughs, and spawning new industries.]

b. **Obtain, evaluate, and communicate information about a technology that draws on natural resources to improve health of people and the natural environment, and was eventually found to have negative impacts, requiring regulations on its use or new technologies to reduce its negative impacts.** [Clarification Statement: Examples include the introduction of new chemicals for refrigeration that were less toxic, but were later found to reduce the ozone layer; the adoption of fossil fuels for energy that eliminated the need to decimate forests for heating and cooking, but were later found to change the atmosphere and climate.]

c. **Construct an explanation for how a technological system has changed over time, based on evidence about how these changes were driven by: (1) people's changing needs, desires, and values, (2) the findings of scientific research, and (3) factors such as climate, natural resources, and economic conditions.** [Clarification Statement: Use diagrams, timelines, or other representations to show factors that have shaped a major technological system over time (e.g., energy, transportation, manufacturing, food production and distribution).] [Assessment Boundary: Explanations do not need to include all possible factors or be quantitative.]

d. **Construct arguments for and against the development of a new technology based on potential short and long term impacts (positive and negative) on the health of people, and the natural environment.** [Clarification Statement: Students should consider the pros and cons of different new technologies such as maglev rail, genetically engineered crops, wearable computers, human space travel, and new energy systems that exploit renewable resources.]

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

Science and Engineering Practices

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 scientific knowledge, principles, and theories.

- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. (a),(c)
- Apply scientific knowledge to explain real-world examples or events and solve design problems. (a),(c)

·gaging in Argument from Evidence
·gaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Use oral and written arguments supported by empirical evidence and reasoning to support or refute an argument for a phenomenon or a solution to a problem. (d)

Obtaining, Evaluating, and Communicating Information
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods.

- Generate and communicate ideas using scientific language and reasoning. (b)
- Gather, read, and explain information from appropriate sources and evaluate the credibility of the publication, authors, possible bias of the source, and methods used. (b)

Disciplinary Core Ideas

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

- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (a)
- In order to design better technologies, new science may need to be explored. (a)
- Technologies in turn extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (a)

ETS2.B: Influence of Engineering, Technology, and Science on society and the natural world

- All human activity draws on natural resources and has both short-term and long-term consequences, positive as well as negative for the health of both people and the natural environment. (b),(d)
- The uses of technology and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (c),(d)
- Thus technology use varies from region to region and over time. (c)
- Technologies that are beneficial for a certain purpose may later be seen to have impacts that were not foreseen. In such cases, new regulations on use or new technologies may be required. (b),(d)

Crosscutting Concepts

Cause and Effect
Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomenon may have more than one cause, and some cause, and effect relationships in systems can only be described using probability. (a),(c),(d)

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale. Small changes in one part of a system might cause large changes in another part. Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms. (b),(c),(d)

Connections to other DCIs in this grade-level: **MS.ESS-ESP, MS.ESS-WC, MS.ESS-HI, MS.LS-GDRO, MS.PS-WER, MS.ETS-ED**

Articulation to DCIs across grade-levels: **3.IF, 3.WCI, 4.LCT, 4.WAV, 5.ESI, 5.SSS, HS.ETS-ETSS**

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

ELA –

RST.6.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
W.6.1 Write arguments to support claims with clear reasons and relevant evidence
W.7.1 Write arguments to support claims with clear reasons and relevant evidence
W.8.1 Write arguments to support claims with clear reasons and relevant evidence
WHST.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Mathematics –

MP 1 Make sense of problems and persevere in solving them.
MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
MP.6 Attend to precision.
6.EE Apply and extend previous understandings of arithmetic to algebraic expressions
Represent and analyze quantitative relationships between dependent and independent variables.
7.RP Analyze proportional relationship and use them to solve real-world and mathematical problems.
7.EE Solve real-life and mathematical problems using numerical and algebraic expressions and equations.
Use functions to model relationships between quantities.