Arizona Science Standards
2018

Arizona Department of Education
High Academic Standards for Students

Introduction

Students are naturally curious about the world and their place in it. Sustaining this curiosity and giving it a scientific foundation must be a high priority in Arizona schools. Scientific thinking enables Arizona students to strengthen skills that people use every day: solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing lifelong learning. A fundamental goal of science education is to help students determine how the world works and make sense of phenomena in the natural world. Phenomena are observable events that can be explained or explored. Science aims to explain the causes of these events, or phenomena, using scientific ideas, concepts, and practices (3-dimensions). Sense-making in science is a conceptual process in which a learner actively engages with phenomena in the natural world to construct logical and coherent explanations that incorporate their current understanding of science or a model that represents it and are consistent with the available evidence. To develop a scientific understanding of the natural world, students must be able to ask questions, gather information, reason about that information and connect it to scientific principles, theories, or models, and then effectively communicate their understanding and reasoning.

Purpose of the Arizona Science Standards

The Arizona Science Standards present a vision of what it means to be scientifically literate, and college and career ready. These standards outline what all students need to know, understand, and be able to do by the end of high school and reflect the following shifts for science education:

- Organize standards around thirteen core ideas and develop learning progressions to coherently and logically build scientific literacy from kindergarten through high school.
- Connect **core ideas**, **crosscutting concepts**, and **science and engineering practices**, to make sense of the natural world and understand how science and engineering are practiced and experienced.
- Focus on fewer, broader standards that allow for greater depth, more connections, deeper understanding, and more applications of content.

The standards are neither curriculum nor instructional practices.
While the Arizona Science Standards serve as the basis for a district's or school's science curriculum, they are not the curriculum. Therefore, identifying the sequence of instruction at each grade – what will be taught and for how long – requires concerted effort and attention at the local level. Curricular tools, including textbooks, are selected by the district/school and adopted through the local governing board. The Arizona Department of Education defines standards, curriculum, and instruction as:

- **Standards** are what a student needs to know, understand, and be able to do by the end of each grade. They build across grade levels in a progression of increasing understanding and through a range of cognitive demand levels. Standards are adopted at the state level by the Arizona State Board of Education.
- **Curriculum** refers to resources used for teaching and learning the standards. Curricula are adopted at the local level.
- **Instruction** refers to the methods or methodologies used by teachers to teach their students. Instructional techniques are employed by individual teachers in response to the needs of the students in their classes to help them progress through the curriculum to master the standards. Decisions about instructional practice and techniques are made at a local level.

Three Dimensions of Science
Sense-making in science occurs with the integration of three essential dimensions:

- **science and engineering practices** (shown as the outer ring in Figure 1)
- **crosscutting concepts** (shown as the middle section of Figure 1)
- **core ideas** (shown as the center circle in Figure 1)

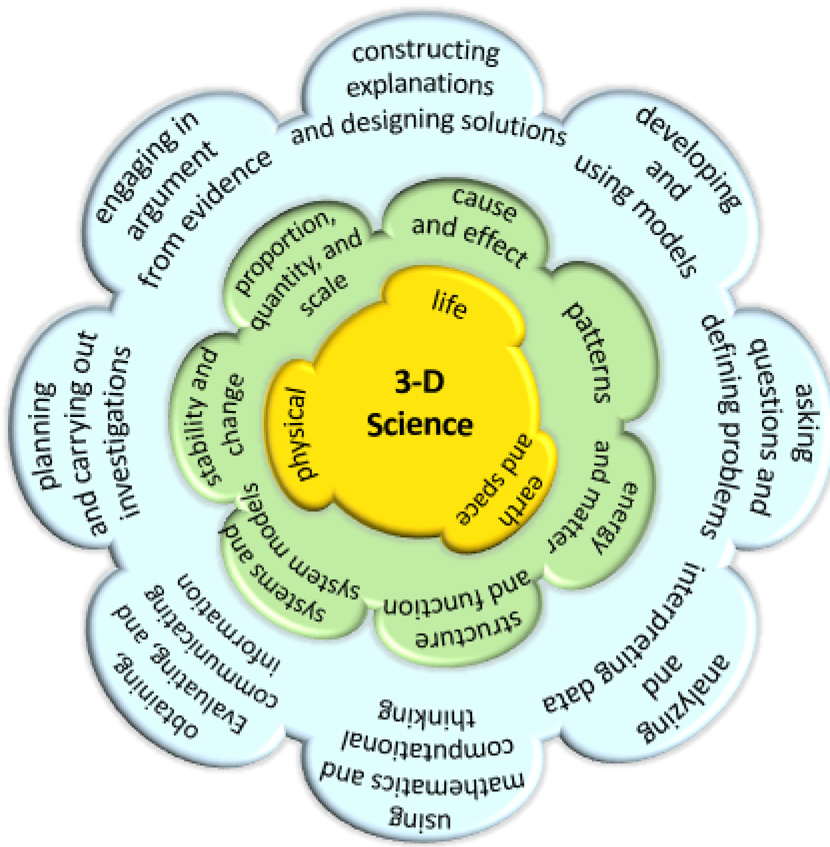


Figure 1: Three Dimensions of Science Instruction

Science and Engineering Practices

For decades teachers have utilized the scientific method as a methodology to engage in scientific inquiry. Traditional implementation often has resulted in viewing science as a linear process. The new vision calls for students to engage in multifaceted science and engineering practices in more complex, relevant, and authentic ways. The science and engineering practices[4] describe a robust process for how scientists investigate and build models and theories of the natural world or how engineers design and build systems. Rather than a linear process from hypothesis to conclusion, these practices reflect science and engineering as they are practiced and experienced. As students conduct investigations, they engage in multiple practices as they gather information to solve problems, answer their questions, reason about how the data provide evidence to support their understanding, and then communicate their understanding of phenomena. Student investigations may be observational, experimental, use models or simulations, or use data from other sources. These eight practices identified in *A Framework for K-12 Science Education*[4] are critical components of scientific literacy, not instructional strategies:

- ask questions and define problems
- develop and use models
- plan and carry out investigations
- analyze and interpret data
- use mathematics and computational thinking
- construct explanations and design solutions
- engage in argument from evidence
- obtain, evaluate, and communicate information

While the scientific method is still being widely used, and a part of academics, the science and engineering practices are expected to be integrated with the core ideas and crosscutting concepts across all grade levels and disciplines. See Appendix 2 for more details on each of the science and engineering practices.

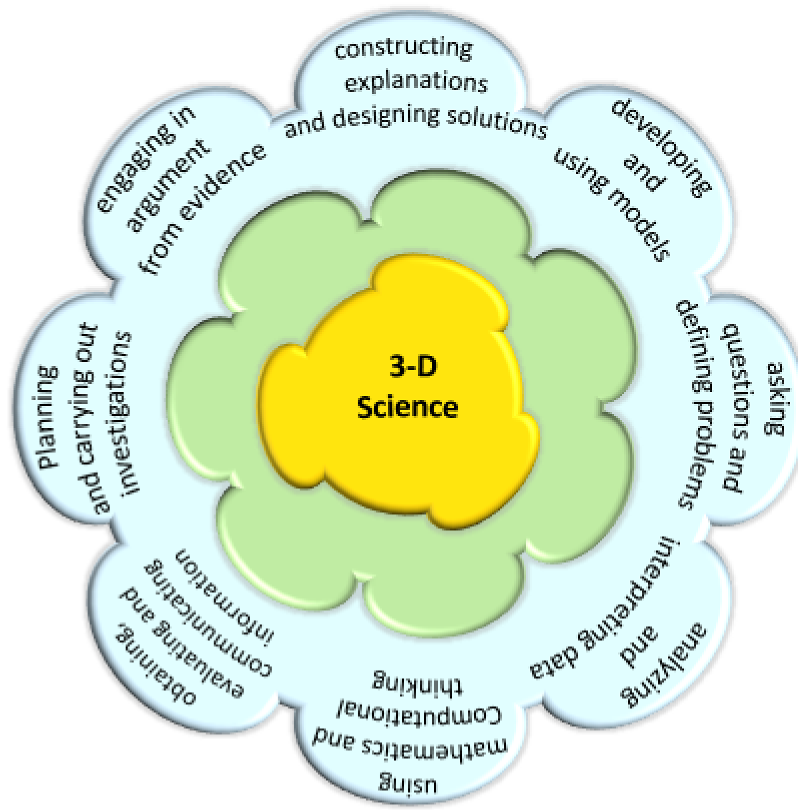


Figure 2: Science and Engineering Practices

Crosscutting Concepts

Crosscutting concepts[4] cross boundaries between science disciplines and provide an organizational framework to connect knowledge from various disciplines into a coherent and scientifically based view of the world. They build bridges between science and other disciplines and connect core ideas and practices throughout the fields of science and engineering. Their purpose is to provide a lens to help students deepen their understanding of the core ideas as they make sense of phenomena in the natural and designed worlds. The crosscutting concepts identified in *A Framework for K-12 Science Education* are:

- patterns
- cause and effect
- structure and function
- systems and system models
- stability and change
- scale, proportion, and quantity
- energy and matter

The Arizona Science Standards are designed for students to develop their understanding of core ideas through the lens of one or multiple crosscutting concepts. Crosscutting concepts can be combined as students find and use patterns as evidence, determine cause and effect relationships, or define systems to investigate. Students must be provided with structures and opportunities to make explicit connections between their learning and the crosscutting concepts. See Appendix 1 for more details on each of the crosscutting concepts.

The use of crosscutting concepts can be demonstrated within cause and effect relationships. For example, researchers investigate cause and effect mechanisms in the motion of a single object, specific chemical reactions, population changes in an ecosystem, and the development of holes in the polar ozone layers. Patterns are present in all science disciplines, and much of science is about explaining observed patterns. Using data, graphs, charts, maps, and statistics in combination with the science and engineering practices, students can use their knowledge of cause and effect relationships to formulate investigations, answer questions, and make informed predictions about observed phenomena.

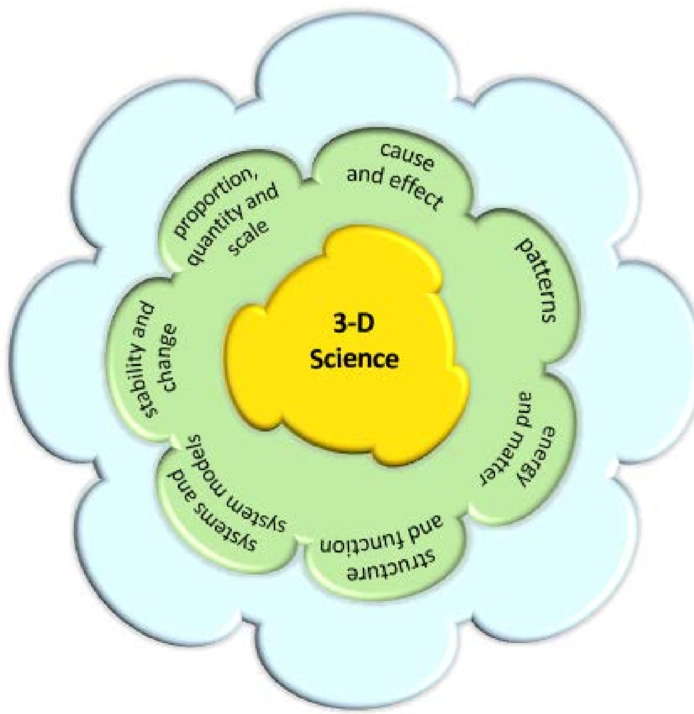


Figure 3: Crosscutting Concepts

Core Ideas

The Arizona Science Standards focus on thirteen core ideas in science and engineering, adapted from *Working with Big Ideas of Science Education.*[2] The ten core ideas for **Knowing Science** center on understanding the causes of phenomena in physical, earth and space, and life science. The three core ideas for **Using Science** connect scientific principles, theories, and models; engineering and technological applications; and societal implications to the content knowledge to support that understanding. The complexity of each core idea develops as students' progress through each grade band. Each standard is written at the intersection of two core ideas to help students understand both the process of knowing science and using science. These core ideas occur across grade levels and provide the background knowledge for students to develop sense-making around phenomena in the natural world. See Appendix 3 for more details. The core ideas are listed below.

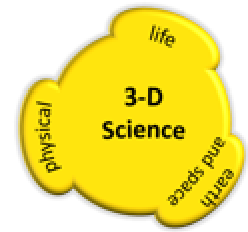


Figure 3: Core Ideas

Core Ideas for Knowing Science		Core Ideas for Using Science
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution. ***Adapted from *Working with Big Ideas in Science Education*[2]**		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

Time Allotment

The Arizona Science Standards suggest students have regular standards-based science instruction every year. The amount of time individual students need to learn these standards will vary. The chart below specifies the instructional time necessary for students to master these standards.

The Arizona Science Standards have been designed so that these time suggestions provide adequate time to actively engage in all 3 dimensions of science instruction to master the standards for each grade level. *Depending on local factors, schools may allocate more or less time when determining curriculum programming within a specific context. Instruction on the Arizona Science Standards may be a dedicated time in the school schedule or may be integrated with the instruction of other subjects.* See Appendix 5 and the Standards document for connections with other content areas.

These time recommendations do not explicitly address the needs of students who are far below or far above the grade level.
No set of grade-specific standards can fully reflect the variety of abilities, needs, learning rates, and achievement levels of students in any given classroom. The Arizona Science Standards do not define the intervention methods to support students who are far below or far above grade level or do not speak English as their first language. See Appendix 4 for strategies to support equity and diversity in science.

Grade	Suggested Minutes per Week	Suggested Average Minutes per Day
K	90 minutes/week	18 minutes/day
1	150 minutes/week	30 minutes/day
2	150 minutes/week	30 minutes/day
3	200 minutes/week	40 minutes/day
4	225 minutes/week	45 minutes/day
5	225 minutes/week	45 minutes/day
6	250 minutes/week	50 minutes/day
7	250 minutes/week	50 minutes/day
8	250 minutes/week	50 minutes/day
HS (3 credits)	275 minutes/week	55 minutes/day

Safety Expectations

While there are no specific standards that address laboratory or field safety, it is a required part of science education to instruct and guide students in using appropriate safety precautions for all investigations. Reducing risk and preventing accidents in science classrooms begins with planning that meets all local, state, and federal requirements, including Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) requirements for safe handling and disposal of laboratory materials. The following four steps are recommended for carrying out a hazard and risk assessment for any investigation[5]:

1) Identify hazards. Hazards may be physical, chemical, health, or environmental.
2) Evaluate the type of risk associated with each hazard.
3) Instruct students on all procedures and necessary safety precautions in such a way as to eliminate or reduce the risk associated with each hazard.
4) Prepare for any emergency that might arise despite all the required safety precautions.

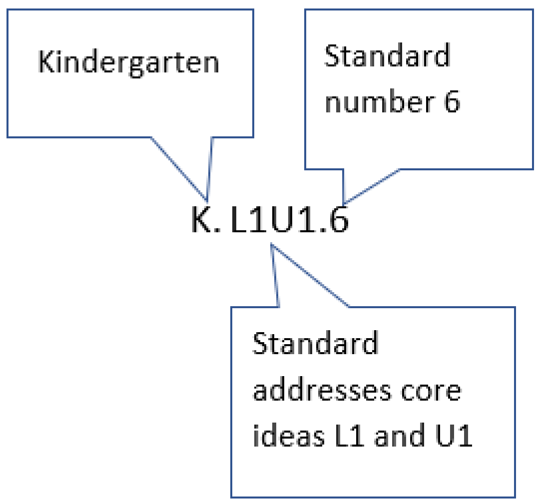
Chemical Storage Expectations

What You Can Do

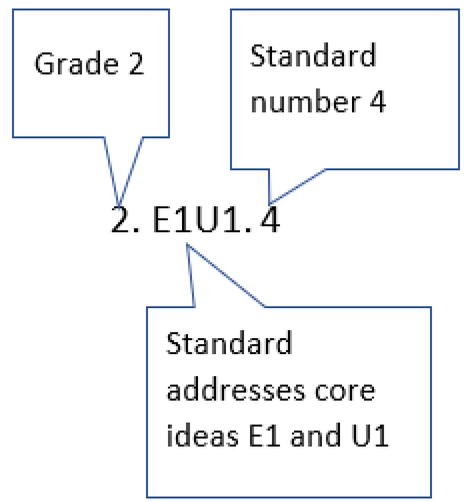
- Put in place an experienced leadership team to oversee chemical management, storage, and handling activities.
- Implement pollution prevention and green chemistry (safer alternatives) principles to minimize the use of hazardous chemicals at schools.
- Establish an environmentally preferable purchasing policy and conduct periodic chemical inventories to identify hazards.
- Train school personnel on hazardous chemicals management and safety.
- Create an emergency response and spill clean-up plan. Communicate with school personnel and students about the plan and the chemicals and products in the school.
- EPA's Chemicals under the Toxic Substance Control Act (TSCA) provides information about this law which protects us from the potential risks of pesticides and toxic chemicals.
- The Center for Disease Control's Facts about Mercury in Schools provides information for school administrators, faculty, staff, local health jurisdictions, and parent groups on how to reduce the hazards of mercury on children's health, avoid chemical liabilities, develop planning tools, and establish collection programs for mercury.
- Chemical Management in Schools is addressed by the Colorado Department of Public Health and Environment, including guidance on self-certification for school laboratories, inventory procedures, lists of common chemical hazards and prohibited or restricted chemicals, and more.
- The School Chemistry Laboratory Safety Guide presents information about ordering, using, storing, and maintaining chemicals in the high school laboratory. The guide also provides information about chemical waste, safety, and emergency equipment, assessing chemical hazards, common safety symbols, signs, and fundamental resources relating to chemical safety, such as Material Safety Data Sheets and Chemical Hygiene Plans, to help create a safe environment for learning. Also, checklists are provided for both teachers and students that highlight important information for working in the laboratory and identify hazards and safe work procedures.

Coding of the K-8 Science Standards

Each K-8 standard represents the intersection of core ideas for knowing science and using science. This intersection stresses that content in physical science, earth and space science, and life science is not learned independently from ideas about the nature of science, applications of science, or the social implications of using science. The coding of the standard captures this intersection. Students engage in multiple practices as they gather information to solve problems, answer their questions, reason about how the data provide evidence to support their understanding, and then communicate their understanding of phenomena, applications, or social implications. They use the crosscutting concepts to support their understanding of patterns, cause and effect relationships, and systems thinking as they make sense of phenomena. The standard number at the end of the code is designed for recording purposes and does not imply instructional sequence or importance. **The images below** are examples and descriptions of coding of the K-8 Standards.



K. L1U1.6 Obtain, evaluate, and communicate information about how organisms use different body parts for survival.



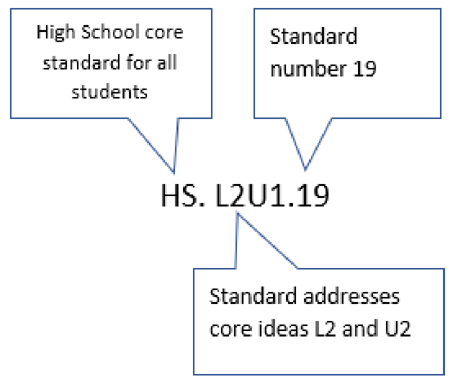
2.E1U1.4 Observe and investigate how wind and water change the shape of the land resulting in a variety of landforms.

Coding of the High School Science Standards

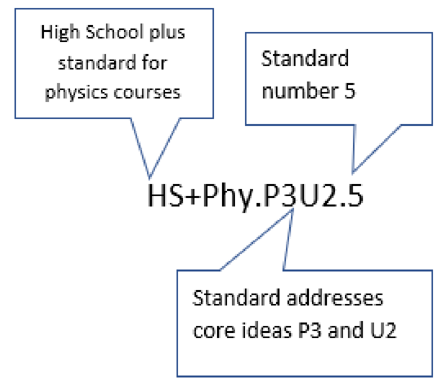
In Arizona, students are required to take 3 credits of high school science aligned to standards in physical, earth and space, and life sciences to meet graduation requirements, but there is no mandatory course sequence across the state. Because of this, the high school standards are written at two levels: essential and plus.

- All high school essential standards (HS) should be learned by every high school student regardless of the 3-credit course sequence they take. The full set of essential high school (HS) standards is designed to be taught over a 3-year period.
- The high school plus (HS+) standards are designed to enhance the rigor of general science courses by extending the essential standards within general chemistry (HS+C), physics (HS+Phy), earth and space sciences (HS+E), or biology (HS+B) courses. These HS+ standards are intended to provide the additional rigor of these courses to prepare students for college courses for science majors.

Like K-8, each high school standard represents the intersection of core ideas for knowing science and using science. This intersection stresses that content in physical science, earth and space science, and life science is not learned independently from ideas about the nature of science, applications of science, or the social implications of using science. The coding of the standard captures this intersection. Students engage in multiple practices as they gather information to solve problems, answer their questions, reason about how the data provide evidence to support their understanding, and then communicate their understanding of phenomena, applications, or social implications. They use the crosscutting concepts to support their understanding of patterns, cause and effect relationships, and systems thinking as they make sense of phenomena. The standard number at the end of the code is designed for recording purposes and does not imply instructional sequence or importance. **At right** are examples and descriptions of coding of the High School Science Standards.



HS. L2U1.19 Develop and use models that show how changes in the transfer of matter and energy within an ecosystem and interactions between species may affect organisms and their environment.



HS+Phy.P3U2.5 Design, evaluate, and refine a device that minimizes or maximizes the force on a macroscopic object during a collision.

Navigating the Standards Document

Standards	Support Material
1.L2U2.7	**Crosscutting Concepts & Background Information for Educators**
Develop and use models about how living things use resources to grow and survive; **design and evaluate** habitats for organisms using earth materials.	**Crosscutting Concepts:** Patterns, **Cause and Effect**, Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4]
1.L2U1.8	**Background Information:** **Animals** depend on their surroundings to get what they need, including **food**, **water**, **shelter**, and a **favorable temperature.** Animals depend on **plants** or other animals for food. They use their **senses** to find food and water, and they use their **body parts** to gather, catch, eat, and chew the food. Plants depend on **air**, water, **minerals** (in the soil), and **light** to grow. Animals can move around, but plants cannot, and they often depend on animals for pollination or to move their **seeds** around. Different plants survive better in different settings because they have varied needs for water, minerals, and sunlight [1(. 151)] Animals need food that they can break down, which comes either directly by eating plants (herbivores) or by eating animals (carnivores) which have eaten plants or other animals. [2(p. 27)] Designs can be conveyed through **sketches, drawings**, or **physical models.**[1(p. 207)] Because there is always more than one possible solution to a problem, it is useful to **compare** designs, **test** them, and **discuss** their **strengths** and **weaknesses.**[1(p. 209)]
Construct an explanation describing how organisms obtain resources from the environment including materials that are used again by other organisms.	

Guide to Explain Standards

Standards	Support Material
The standards are what is expected for students to master at the end of the grade level and are intended to be the content utilized for the state assessment. They contain the disciplinary core ideas and **the science and engineering practices (SEPs)** that are in bold in the standard. It may take several science and engineering practices to reach the desired level of depth of content. These are expected to be learned over the course of the year throughout multiple standards.	**The Crosscutting Concepts and Background Information for Educators** is a guidance resource embedded into the standards document. This is the first step to deepen content knowledge and to make apparent the research behind the standard. The learning progression is supporting material and not the basis for assessment. **The crosscutting concepts listed** connect to other standards for themes and integrated science instruction, one of the key components of three-dimensional science instruction. **Bold** crosscutting concepts indicate the concepts that are across the grade level. Example: cause and effect and stability and change are dominant crosscutting concepts for first grade.

Rationale of Changes to the 2018 Standards Document

Changes have been made to the standards document while NO changes have been made to the standards themselves. To better support the implementation of standards, slight modifications were made only to the right side of this document.

Date	Changes	Rationale
4/5/19 10/19/19	Grammar and formatting.	Consistency throughout document.
7/26/19	Introduction section 4th sentence Phenomena are observable events that can be explained or explored. Science seeks to explain the causes of phenomena using scientific practices, ideas, and concepts.	Clarity on what phenomena is.
7/26/19	"Learning Progressions, Key Terms, and Crosscutting Concepts" was retitled to "Crosscutting Concepts & Background Information for Educators" on the right side of the standards document.	To ensure the information from *A Framework for K-12 Science Education* and *Working with Big Ideas of Science Education* was being used as background education for the educator. This is not a sequence of learning, but rather provides background content knowledge for the educator on the resource that was utilized when writing the standards.
7/26/19	The Crosscutting Concepts were moved from the bottom of the page to the top of the page.	The Crosscutting Concepts were moved to show that they are not an afterthought.
8/8/19	All 7 Crosscutting Concepts are listed, instead of just the "focus" CCC for each grade level.	To ensure educators understand that there are 7 CCCs in total, and further explain that the **bolded** CCCs are the "focus" crosscutting concepts for that particular grade level.
8/8/19	Replaced and updated the graphic used on page 11 to match the updates to the right side of the document.	Updated image to match the updated right side of the standards document.
8/8/19	Under the sections titled "Background Information" the font was changed from 10 point to 9 point.	To better format the document and try to avoid page breaks within a standard.
9/25/19	Physical 6.1-3 Standard *Teacher Background* change	Added: Info from pg. 108 Framework Reason: No information in original regarding temperature and pressure to give deeper background on standard regarding substances.
9/25/19	Life 7.10-12 Standard *Teacher Background* change	Added/Moved: Info from 6th grade life standards from the background information (6.11-14), to Life 7th grade standards 10-12. Reason: The information connects better to 7th grade life than it did to 6th grade life. Identified by ASTA 5 Tools team while making unpacking cards.
9/25/19	7.E1U1.5 Standard *Teacher Background* change	Added/Moved: Info from 7.E1U1.7 earth standard from the background to 7.E1U1.5 standard Reason: This section was moved from standard 7 to standard 5 because 5 discusses the "science knowledge" this background addresses. Standard 7 was about the technology and engineering. Info from the Framework was added to 7 to meet the technology needs of standard 7.
9/25/19	7.E1U2.7 Standard *Teacher Background* change	Added: Info from pg. 194 from the Framework to *Teacher Background* Reason: To address the part of 7th grade standard 7/this is a U2 standard and the part of the standard that addresses technology used to predict weather.

9/25/19	7.L1U1.9	Added: Info from pg. 144 from the Framework to *Teacher Background* Reason: Need to add information to *Teacher Background* from A Framework to address to address the function of the cell membrane.
9/25/19	7th grade L1 standards	Merged the box for all L1 life standards. The Teacher Background fits all these L1 standards, it was repetitive before. The single L2 standard was left in its own box. Information added to Teacher Background, see note below:
9/25/19	7.L2U1.12	Added: Info from pg. 144 from the Framework to *Teacher Background* Reason: Need to add information to *Teacher Background* from A Framework to address to address the function of the cell membrane. (List some actual structures in the cell)
9/25/19	7.L2U1.8-9	Moved: "Life is the quality that distinguishes living things - composed of living cells, from nonliving objects or those that have died. While a simple definition of life can be difficult to capture, all living things - that is to say all organisms - can be characterized by common aspects of their structure and functioning." From lower in the *Teacher Background* box, to higher up in the *Teacher Background*. Reason: To allow for better flow of information. (Like with Like)
9/25/19	8.3- physical	Added: Teacher Background from pg. 23 of Big Ideas Reason: Added to further explain the transfer of energy
9/25/19	7.P3U1.4	Added: Teacher Background from pg. 115-116 A Framework Reason: Clarify what shape and orientation means for forces
10/16/19	8.P1U1.1-2	Added: Section from page 111 from the Framework Reason: Added from Framework to include all research when writing standards.
10/16/19	6.P2U1.4	Added: Section from page 118 from the Framework Reason: Added from Framework to include all research when writing standards.
10/16/19	6E1U1.6	Added: Section from page 188 from the Framework Reason: Added from Framework to include all research when writing standards.
10/19/19	Page 4- Science and Engineering Practices, the second sentence was changed	Changed second sentence to "Traditional implementation often has resulted in viewing science as a linear process" for clarity.
10/19/19	Page 5- Crosscutting Concepts, the second sentence was changed.	Changed second sentence to "They build bridges between science and other disciplines and connect core ideas and practices throughout the fields of science and engineering" for clarity.

Grades K-2 Science Standards

The K-2 Science Standards are designed to provide opportunities for students to develop an understanding of all thirteen core ideas (see Appendix 3) across the K-2 grade band. To sufficiently demonstrate knowledge, understanding, and performance of each standard, not every core idea is included in every grade.

Students engage in multiple science and engineering practices as they gather information to answer their questions or solve design problems by reasoning how data provides evidence to support their understanding, and then communicate their understanding of phenomena in physical, earth and space, and life sciences (the knowing of science). Students apply their knowledge of the core ideas to understand phenomena, see the impact, or construct technological solutions (using science). The crosscutting concepts support their understanding of patterns, cause and effect relationships, and systems thinking as students make sense of phenomena in the natural and designed worlds. The practices, core ideas, and crosscutting concepts help students develop an understanding of skills and knowledge to transfer them from one grade to the next and between content areas.

- In kindergarten, students use their senses to help them make observations about the world around them, recognizing patterns and the structures and functions of living and non-living things.
- In first grade, students develop an understanding of causal relationships as they investigate how objects can impact other objects from a distance or by contact with each other. They also develop systems thinking as they investigate how organisms interact with Earth for survival, and how life systems have cycles.
- In second grade, students develop an understanding of systems and system models along with energy and matter. Students develop an understanding of observable properties of matter, how energy changes matter, the distribution, and role of water and wind, and how life on Earth depends on an energy source.

The organization of the standards within this document does not indicate instructional sequence or importance. Decisions about curriculum and instruction are made locally by individual school districts and classroom teachers; these standards can be sequenced, combined, or integrated with other content areas to best meet the local curriculum or student needs (See Appendices 5 and 6). It is suggested to use the metric system for measurement, as most scientific tools utilize the metric system.

Kindergarten: Focus on Patterns; Structure and Function

By the end of Kindergarten, students learn to use their senses to help them make observations and predictions about the world around them. In this grade level, students will investigate how the senses detect light and sound, observe weather patterns and their influences on plants and animals, and differentiate between systems and structures of living and non-living things. Student investigations focus on collecting and making sense of observational data and simple measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, use evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in Kindergarten focus on helping students understand phenomena through the crosscutting concepts of patterns and structure and function.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students explore how their senses can detect light, sound, and vibration and how technology can be used to extend their senses.

Physical Science Standards	Crosscutting Concepts and Background Information for Educators
K.P2U1.1 **Investigate** how senses can detect light, sound, and vibrations even when they come from far away; use the collected evidence to **develop and support an explanation.** **K.P2U2.2** **Design and evaluate** a tool that helps people extend their senses.	**Crosscutting Concepts:** **Patterns**; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function;** Stability and Change[4] **Background Information:** People use their **senses** to learn about the world around them. Their **eyes** detect light, their **ears** detect sound, and they can feel vibrations by **touch**. People also use a variety of devices to communicate (send and receive information) over long distances.[4 (p. 137)] Objects can have an effect on other objects even when they are not in contact with them. For instance, **light** affects the objects it reaches, including our eyes. Objects that are seen either give out or **reflect** light that human eyes can detect. **Sound** comes from things that **vibrate** and can be detected at a distance from the source because the air or other material around is made to vibrate. Sounds are heard when the vibrations in the air enter our ears.[2 (p. 21)] Designs can be conveyed through **sketches**, **drawings**, or **physical models.**[4 (p. 207)] Because there is always more than one possible solution to a problem, it is useful to **compare** designs, **test** them, and **discuss** their **strengths** and **weaknesses.**[4 (p. 209)]

Earth and Space Sciences: Students develop an understanding of patterns to understand changes in local weather, seasonal cycles, and daylight.

Earth and Space Standards	Crosscutting Concepts & Background Information for Educators
K.E1U1.3 **Observe, record, and ask questions** about temperature, precipitation, and other weather data to identify patterns or changes in local weather. **K.E1U1.4** **Observe, describe, ask questions, and predict** seasonal weather patterns; and how those patterns impact plants and animals (including humans).	**Crosscutting Concepts:** **Patterns**; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** There is air all around the Earth's surface, but there is less and less further away from the surface (higher in the sky). **Weather** is determined by the conditions and movement of the air. The **temperature**, **pressure**, **direction**, **speed** of movement and the amount of **water vapor** in the air combine to create the weather. Measuring these properties over time enables patterns to be found that can be used to **predict** the weather a short time ahead.[2] (p. 24)
K.E2U1.5	**Crosscutting Concepts & Background Information for Educators**
Observe and ask questions about patterns of the motion of the sun, moon, and stars in the sky.	**Crosscutting Concepts:** **Patterns**; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function;** Stability and Change[4] **Background Information:** Patterns of the motion of the **sun, moon, and stars** in the sky can be observed, described, and predicted. At night one can see the light coming from many stars with the naked eye, but **telescopes** make it possible to see many more and to observe them and the moon and **planets** in greater detail.[4] (p. 174)

Life Sciences: Students develop an understanding that the world is comprised of living and non-living things. They investigate the relationship between structure and function in living things; plants and animals use specialized parts to help them meet their needs and survive.

Life Science Standards	Crosscutting Concepts & Background Information for Educators
K.L1U1.6	**Crosscutting Concepts:** **Patterns**; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function;** Stability and Change[4] **Background Information:** All **organisms** have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in **food**, **water,** and **air**. **Plants** also have different parts (**roots, stems, leaves, flowers, fruits**) that help them survive, grow, and produce more plants. [4](p. 144) Animals have **body parts** that capture and convey different kinds of information needed for **growth** and **survival**—for example, **eyes** for light, **ears** for sounds, and **skin** for temperature or touch. Animals **respond** to these **inputs** with behaviors that help them survive (e.g., find food, run from a **predator**)[4] (p. 149)
Obtain, evaluate, and communicate information about how organisms use different body parts for survival.	
K.L1U1.7	
Observe, **ask questions, and explain** how specialized structures found on a variety of plants and animals (including humans) help them sense and respond to their environment.	
K.L2U1.8	**Crosscutting Concepts & Background Information for Educators**
Observe, **ask questions**, **and explain** the differences between the characteristics of living and non-living things.	**Crosscutting Concepts:** **Patterns**; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function;** Stability and Change[4] **Background Information:** There is a wide variety of **living** things (organisms), including **plants** and **animals**. They are distinguished from **non-living** things by their ability to **move**, **reproduce,** and react to certain **stimuli**.[2] (p. 26)

First Grade: Focus on Cause and Effect; Stability and Change (cycles)

By the end of first grade, students make observations to understand the connections between earth materials and the ability for Earth to sustain a variety of organisms. Students learn how objects can impact other objects from a distance or by contact with each other, how organisms interact with earth materials for survival, and how life systems have cycles. Student investigations focus on collecting and making sense of observational data and simple measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, use evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in first grade focus on helping students understand phenomena through cause and effect and stability and change.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students develop an understanding of the effects of forces and waves, and how they can impact or be impacted by objects near and far away. They explore the relationships between sound and vibrating materials, as well as light and materials including the ability of sound and light to travel from place to place.

Physical Science Standards	Crosscutting Concepts & Background Information for Educators
1.P2U1.1	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4] **Background Information:** Some materials allow **light** to pass through them, others allow only some light through, and others block all the light and create a dark **shadow** on any surface beyond them (i.e., on the other side from the light source), where the light cannot reach. **Mirrors** and **prisms** can be used to redirect a light beam. [4 (p. 134-135)] Light and sound are **wavelike** phenomena. **Sound** can make **matter vibrate**, and vibrating matter can make sound. [4 (p. 132)]
Plan and carry out investigations demonstrating the effect of placing objects made with different materials in the path of a beam of light and **predict** how objects with similar properties will affect the beam of light.	
1.P2U1.2	
Use models to provide evidence that vibrating matter creates sound and sound can make matter vibrate.	
1.P3U1.3	**Crosscutting Concepts & Background Information for Educators**
Plan and carry out investigations which demonstrate how equal forces can balance objects and how unequal forces can push, pull, or twist objects, making them change their speed, direction, or shape.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4] **Background Information:** **Forces** can **push**, **pull** or **twist** objects, making them change their **motion** or **shape**. Forces act in particular directions. **Equal forces** acting in opposite directions in the same line cancel each other and are described as being in **balance**. The movement of objects is changed if the forces acting on them are not in balance. [2 (p. 22)]

1.P4U2.4	Crosscutting Concepts & Background Information for Educators
Design and evaluate ways to increase or reduce heat from friction between two objects.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4] **Background Information:** When two objects rub against each other, this interaction is called **friction**. Friction between two surfaces can warm both of them (e.g., rubbing hands together). There are ways to reduce the friction between two objects.[4 (p. 129)] Designs can be conveyed through **sketches**, **drawings**, or **physical models.**[4 (p. 207)]Because there is always more than one possible solution to a problem, it is useful to **compare** designs, **test** them, and **discuss** their **strengths** and **weaknesses.**[4 (p. 209)]

Earth and Space Sciences: Students develop an understanding that earth materials are essential for organism's survival.

Earth and Space Standards	Crosscutting Concepts & Background Information for Educators
1.E1U1.5 **Obtain, evaluate, and communicate information** about the properties of Earth materials and **investigate** how humans use natural resources in everyday life.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4] **Background Information:** Wind and water can change the shape of the land. The resulting **landforms**, together with the materials on the land, provide homes for **living things**. [4 (p. 180)] Humans use **natural resources** for everything they do: for example, they use **soil** and **water** to grow **food**, **wood** to burn to provide **heat** or to build **shelters**, and materials such as **iron** or **copper (minerals)** extracted from Earth to make cooking pans.[4 (p. 192)]

Life Sciences: Students develop an understanding that Earth has supported, and continues to support, a large variety of organisms. These organisms can be distinguished by their physical characteristics, life cycles, and their different resource needs for survival. Different types of organisms live where there are different earth resources such as food, air, and water.

Life Science Standards	Crosscutting Concepts & Background Information for Educators
1.L1U1.6 **Observe, describe, and predict** life cycles of animals and plants.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4] **Background Information:** **Plants** and **animals** have predictable **characteristics** at different **stages of development**. Plants and animals **grow** and change. Adult plants and animals can have **young**.[4(p. 146)]
1.L2U2.7	**Crosscutting Concepts & Background Information for Educators**
Develop and use models about how living things use resources to grow and survive; **design and evaluate** habitats for organisms using earth materials. **1.L2U1.8** **Construct an explanation** describing how organisms obtain resources from the environment including materials that are used again by other organisms.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4] **Background Information:** **Animals** depend on their surroundings to get what they need, including **food**, **water**, **shelter**, and a **favorable temperature**. Animals depend on **plants** or other animals for food. They use their **senses** to find food and water, and they use their **body parts** to gather, catch, eat, and chew the food. Plants depend on **air**, water, **minerals** (in the soil), and **light** to grow. Animals can move around, but plants cannot, and they often depend on animals for pollination or to move their **seeds** around. Different plants survive better in different settings because they have varied needs for water, minerals, and sunlight [4(. 151)] Animals need food that they can break down, which comes either directly by eating plants (herbivores) or by eating animals (carnivores) which have eaten plants or other animals. [2(p. 27)] Designs can be conveyed through **sketches**, **drawings**, or **physical models.**[4(p. 207)] Because there is always more than one possible solution to a problem, it is useful to **compare** designs, **test** them, and **discuss** their **strengths** and **weaknesses.**[4(p. 209)]

1.L3U1.9	Crosscutting Concepts & Background Information for Educators
Obtain, evaluate, and communicate information to **support an** evidence-based explanation that plants and animals produce offspring of the same kind, but offspring are generally not identical to each other or their parents.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4] **Background Information:** **Living** things produce **offspring** of the same kind, but offspring are not **identical** with each other or with their **parents**. Plants and animals, including humans, resemble their parents in many features because information is passed from one **generation** to the next.[2 (p. 22)] Organisms have **characteristics** that can be similar or different. Young animals are very much, but not exactly, like their parents and also resemble other animals of the same kind. Plants also are very much, but not exactly, like their parents and resemble other plants of the same kind.[4 (p. 158)]
1.L4U1.10	**Crosscutting Concepts & Background Information for Educators**
Develop a model to describe how animals and plants are classified into groups and subgroups according to their similarities. **1.L4U3.11** Ask questions and explain how factors can cause species to go extinct.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; **Stability and Change**[4] **Background Information:** There are many different kinds of **plants** and **animals** in the world today and many kinds that once lived but are now **extinct**. We know about these from **fossils**. Animals and plants are **classified** into groups and subgroups according to their **similarities.**[2 (p.29)] Some kinds of plants and animals that once lived on Earth (e.g., dinosaurs) are no longer found anywhere, although others now living (e.g., lizards) resemble them in some ways.[4 (p. 162)]

Second Grade: Focus on Systems and System Models; Energy and Matter

By the end of second grade, students understand the basic concept that energy can change the phase of matter and is necessary for life. Students begin to understand energy and matter, the formation of Earth's surface features, water cycles and energy flow, changes in the environment, patterns in the sky, and the conditions necessary for life on Earth. Student investigations focus on collecting and making sense of observational data and simple measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in second grade focus on helping students understand phenomena through systems and system models and energy and matter.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students develop an understanding of observable properties of matter and how changes in energy (heating or cooling) can affect matter or materials.

Physical Science Standards	**Crosscutting Concepts & Background Information for Educators**
2.P1U1.1 **Plan and carry out an investigation** to determine that matter has mass, takes up space, and is recognized by its observable properties; use the collected evidence to **develop and support an explanation**. **2.P1U1.2** **Plan and carry out investigations** to gather evidence to support an explanation on how heating or cooling can cause a phase change in matter.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; **Systems and System Models**; **Energy and Matter**; Structure and Function; Stability and Change[4] **Background Information:** All the 'stuff' encountered in everyday life, including **air,** water and different kinds of **solid substances**, is called **matter** because it has **mass**, and therefore **weight** on Earth, and takes up space. Different materials are recognizable by their **properties**, some of which are used to classify them as being in the **solid**, **liquid** or **gas state.**[2 (p. 20)] Different kinds of matter exist (e.g., wood, metal, water), and many of them can be either solid or liquid, depending on temperature.[4 (p. 108)])
2.P4U1.3	**Crosscutting Concepts & Background Information for Educators**
Obtain, evaluate and communicate information about ways heat energy can cause change in objects or materials.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; **Systems and System Models**; **Energy and Matter**; Structure and Function; Stability and Change[4] **Background Information:** There are various ways of causing an event or bringing about change in objects or materials. Heating can cause **change**, as in cooking, **melting solids** or changing water to **vapor.**[2 (p. 23)]

Earth and Space Sciences: Students develop an understanding of the distribution and role of water and wind in weather, shaping the land, and where organisms live. Wind and water can also change environments, and students learn humans and other organisms can change environments too. Students develop an understanding of changing patterns in the sky including the position of Sun, Moon, and stars, and the apparent shape of the Moon.

Earth and Space Standards	Crosscutting Concepts & Background Information for Educators
2.E1U1.4	<u>**Crosscutting Concepts:**</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; **Systems and System Models**; **Energy and Matter**; Structure and Function; Stability and Change[4] <u>**Background Information:**</u> **Wind** and **water** can change the shape of the land. The resulting **landforms**, together with the materials on the land, provide homes for living things.[4 (p. 180)] Water is found in the **ocean**, **rivers**, **lakes**, and **ponds**. Water exists as **solid** ice and in **liquid** form. It carries soil and rocks from one place to another and determines the variety of life forms that can live in a particular location.[4 (p. 184)]
Observe and investigate how wind and water change the shape of the land resulting in a variety of landforms.	
2.E1U1.5	
Develop and use models to represent that water can exist in different states and is found in oceans, glaciers, lakes, rivers, ponds, and the atmosphere.	
2.E1U2.6	**Crosscutting Concepts & Background Information for Educators**
Analyze patterns in weather conditions of various regions of the world and **design, test, and refine solutions** to protect humans from severe weather conditions.	<u>**Crosscutting Concepts:**</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; **Systems and System Models**; **Energy and Matter**; Structure and Function; Stability and Change[4] <u>**Background Information:**</u> **Weather** is the combination of **sunlight**, **wind**, **snow** or **rain**, and **temperature** in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice **patterns** over time.[4 (p. 188)] Designs can be conveyed through **sketches**, **drawings**, or **physical models**.[4 (p. 207)]Because there is always more than one possible solution to a problem, it is useful to **compare** designs, **test** them, and **discuss** their **strengths** and **weaknesses**.[4 (p. 209)]

2.E1U3.7	Crosscutting Concepts & Background Information for Educators
Construct an argument from evidence regarding positive and negative changes in water and land systems that impact humans and the environment.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; **Systems and System Models**; **Energy and Matter**; Structure and Function; Stability and Change[4] **Background Information:** Plants and animals (including humans) depend on the **land**, **water**, and **air** to live and grow. They in turn can change their **environment** (e.g., the shape of land, the flow of water).[4 (p. 190)]
2.E2U1.8	**Crosscutting Concepts & Background Information for Educators**
Observe and explain the Sun's position at different times during a twenty-four-hour period and changes in the apparent shape of the Moon from one night to another.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; **Systems and System Models**; **Energy and Matter**; Structure and Function; Stability and Change[4] **Background Information:** There are patterns in the position of the **Sun** seen at different times of the **day** and in the shape of the **Moon** from one **night** to another.[2 (p. 25)]

Life Sciences: Students develop an understanding that life on Earth depends on energy from the Sun or energy from other organisms to survive.

Life Science Standards	Crosscutting Concepts & Background Information for Educators
2.L2U1.9 **Obtain, analyze, and communicate evidence** that organisms need a source of energy, air, water, and certain temperature conditions to survive. **2.L2U1.10** **Develop a model** representing how life on Earth depends on energy from the Sun and energy from other organisms.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; **Systems and System Models**; **Energy and Matter**; Structure and Function; Stability and Change[4] **Background Information:** All living things need food as their source of **energy** as well as air, water, and certain temperature conditions. Plants containing chlorophyll can use **sunlight** to make the food they need and can store food that they do not immediately use. Animals need food that they can break down, which comes either directly by eating plants (herbivores) or by eating animals (carnivores) which have eaten plants or other animals. Animals are ultimately dependent on plants for their survival. The relationships among organisms can be represented as **food chains** and **food webs.**[2] (p. 27) All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow.[4] (p. 147)

Distribution of K-2 Standards

	U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	**U2**: The knowledge produced by science is used in engineering and technologies to create products.	**U3**: Applications of science often have both positive and negative ethical, social, economic, and political implications.
P1: All matter in the Universe is made of very small particles.	2.P1U1.1 2.P1U1.2		
P2: Objects can affect other objects at a distance.	K.P2U1.1 1.P2U1.1 1.P2U1.2	K.P2U2.2	
P3: Changing the movement of an object requires a net force to be acting on it.	1.P3U1.3		
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.	2.P4U1.3	1.P4U2.4	
E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.	K.E1U1.3 K.E1U1.4 1.E1U1.5 2.E1U1.4 2.E1U1.5	2.E1U2.6	2.E1U3.7
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.	K.E2U1.5 2.E2U1.8		
L1: Organisms are organized on a cellular basis and have a finite life span.	K.L1U1.6 K.L1U1.7 1.L1U1.6		
L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.	K.L2U1.8 1.L2U1.8 2.L2U1.9 2.L2U1.10	1.L2U2.7	
L3: Genetic information is passed down from one generation of organisms to another.	1.L3U1.9		
L4: The unity and diversity of organisms, living and extinct, is the result of evolution.	1.L4U1.10		1.L4U3.11

Grades 3-5 Science Standards

The Grades 3-5 Science Standards are designed to provide opportunities for students to develop an understanding of all thirteen core ideas (see Appendix 3) across the 3-5 grade band. To sufficiently demonstrate knowledge, understanding, and performance of each standard, not every core idea is included in every grade.

Within each grade level, students engage in multiple science and engineering practices as they gather information to answer their questions or solve design problems by reasoning how the data provide evidence to support their understanding, and then communicate their understanding of phenomena in physical, earth and space, and life science (the knowing of science). Students apply their knowledge of the core ideas to understand phenomena, see the impact, or construct technological solutions (using science). The crosscutting concepts support their understanding of patterns, cause and effect relationships, and systems thinking as students make sense of phenomena in the natural and designed worlds. The practices, core ideas, and crosscutting concepts help students develop an understanding of skills and knowledge to transfer them from one grade to the next and between content areas.

- In third grade, students develop an understanding of systems and system models along with structure and function involving energy and matter.
- In fourth grade, students apply systems and system models as they investigate how energy and the availability of resources affects Earth systems (geosphere and biosphere). They also develop an understanding of stability and change with regards to how populations of organisms and Earth have changed over time.
- In fifth grade, students apply their understanding of scale at micro levels as they investigate changes in matter and at macro levels as they investigate patterns of genetic information and movement between Earth and Moon.

The organization of the standards within this document does not indicate instructional sequence or importance. Decisions about curriculum and instruction are made locally by individual school districts and classroom teachers; these standards can be sequenced, combined, or integrated with other content areas to best meet the local curriculum or student needs (See Appendices 4 and 5). It is suggested to use the metric system for measurement, as most scientific tools utilize the metric system.

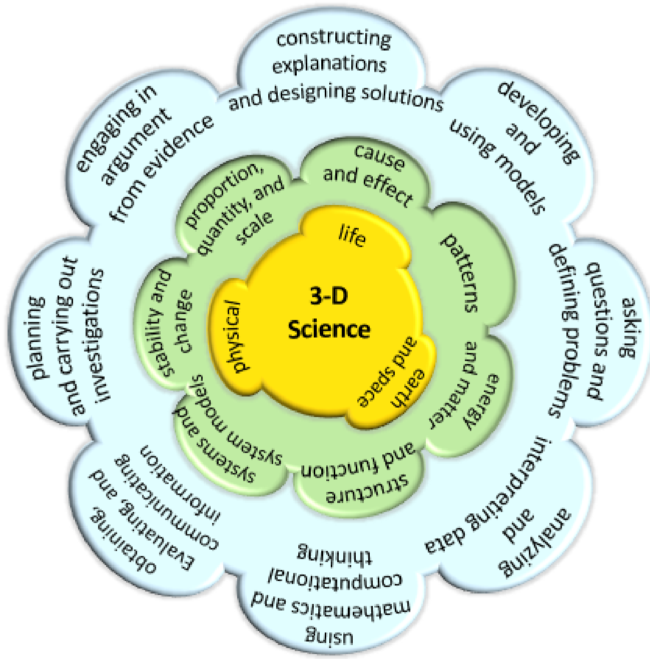


Figure 1: Three Dimensions of Science Instruction

Third Grade: Focus on Systems and System Models; Structure and Function

By the end of third grade, students will gain an understanding of how the Sun provides energy for life on Earth. Students apply their understanding of light and sound waves, how they travel, are detected, and transfer energy. Students learn that organisms have different structures and functions which increase their chances of survival. Student investigations focus on collecting and making sense of observational data and simple measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in third grade focus on helping students understand phenomena through systems and system models and structure and function.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students develop an understanding of the sources, properties, and characteristics of energy along with the relationship between energy transfer and the human body.

Physical Science Standards	Crosscutting Concepts & Background Information for Educators
3.P2U1.1	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity; **Systems and System Models**; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** **Light** is seen because it affects the objects it reaches, including our **eyes**. Sources give out light, which travels from them in various directions and is detected when it reaches and enters our eyes. Objects that are seen either **give out** or **reflect** light that human eyes can **detect**. **Sound** comes from things that **vibrate** and can be detected at a distance from the source because the air or other material around is made to vibrate. Sounds are heard when the vibrations in the air enter our **ears.** [2 (p 21).] An object can be seen when light reflected from its surface enters the eyes; the color people see depends on the color of the available light sources as well as the properties of the surface. Because lenses bend light beams, they can be used, singly or in combination, to provide **magnified** images of objects too small or too far away to be seen with the naked eye.[4 (p. 135)] Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) [4 (p. 132)]
Ask questions and investigate the relationship between light, objects, and the human eye.	
3.P2U1.2	
Plan and carry out an investigation to explore how sound waves affect objects at varying distances.	

3.P4U1.3	Crosscutting Concepts & Background Information for Educators
Develop and use models to describe how light and sound waves transfer energy.	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity; **Systems and System Models**; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** The faster a given object is moving, the more **energy** it possesses. Energy can be moved from place to place by moving objects or through **sound or light**. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.)[4 (p. 122)] Energy is present whenever there are moving objects, sound, light, or **heat**. When objects **collide**, energy can be **transferred** from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. Light also transfers energy from place to place. For example, energy radiated from the sun is transferred to Earth by light. When this light is absorbed, it warms Earth's land, air, and water and facilitates plant growth.[4(p.125)]

Earth and Space Sciences: Students develop an understanding of how the Sun provides light and energy for Earth systems.

Earth and Space Standards	Crosscutting Concepts & Background Information for Educators
3.E1U1.4 **Construct an explanation** describing how the Sun is the primary source of energy impacting Earth systems.	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity; **Systems and System Models**; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** All **Earth processes** are the result of energy flowing and matter cycling within and among Earth's systems. This energy originates from the **sun** and from Earth's interior. [4 (179-180)] Earth's major systems are the **geosphere** (solid and molten rock, soil, and sediments), the **hydrosphere** (water and ice), the **atmosphere** (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes.[4 (181)]

Life Sciences: Students develop an understanding of the flow of energy in a system beginning with the Sun to and among organisms They also understand that plants and animals (including humans) have specialized internal and external structures and can respond to stimuli to increase survival.

Life Science Standards	Crosscutting Concepts & Background Information for Educators
3.L1U1.5 **Develop and use models** to explain that plants and animals (including humans) have internal and external structures that serve various functions that aid in growth, survival, behavior, and reproduction. **3.L2U1.6** **Plan and carry out investigations** to demonstrate ways plants and animals react to stimuli.	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity; **Systems and System Models**; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** Animals have both **internal** and **external** structures that serve various functions in **growth, survival, behavior, and reproduction**. (Boundary: Stress at this grade level focus is on understanding the macroscale systems and their function, not microscopic processes.) [4 (p. 144)]
3.L2U1.7	**Crosscutting Concepts & Background Information for Educators**
Develop and use system models to describe the flow of energy from the Sun to and among living organisms.	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity; **Systems and System Models**; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** The food of almost any kind of **animal** can be traced back to **plants**. Organisms are related in **food webs** in which some animals eat plants. Either way, they are "**consumers**." Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "**decomposers**." Decomposition eventually restores (recycles) some materials back to the soil for plants to use. Organisms can survive only in environments in which their particular needs are met. A healthy **ecosystem** is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.[4 (p. 151)] Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, water, and minerals from the environment and release waste matter (gas, liquid, or solid) back into the environment. [4 (p. 153)]

3.L2U1.8	Crosscutting Concepts & Background Information for Educators
Construct an argument from evidence that organisms are interdependent.	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity; **Systems and System Models**; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** **Animals** and **plants** alike generally need to take in air and water, animals must take in food, and plants need light and **minerals**; **anaerobic** life, such as **bacteria** in the gut, functions without air. Food provides animals with the materials they need for **body repair** and **growth** and is **digested** to release the **energy** they need to maintain body warmth and for motion. Plants acquire their material for growth chiefly from air and water and process matter they have formed to maintain their **internal conditions** (e.g., at night). [4 (p. 148)] Animals need food that they can break down, which comes either directly by eating plants (**herbivores**) or by eating animals (**carnivores**) which have eaten plants or other animals. Animals are ultimately dependent on plants for their survival. The relationships among organisms can be represented as food chains and food webs. Some animals are dependent on plants in other ways as well as for food, for example for shelter and, in the case of human beings, for clothing and fuel. Plants also depend on animals in various ways. For example, many flowering plants depend on insects for pollination and on other animals for dispersing their seeds.[2 (p. 27)]

Fourth Grade: Systems and System Models; Energy and Matter; Stability and Change

By the end of fourth grade, students expand on the idea that energy from the Sun interacts with Earth systems and explore other forms of energy we use in everyday life. Students apply their understanding of the various Earth systems (geosphere, hydrosphere, atmosphere, biosphere) and how they interact with each other and heat from the Sun. Students understand how geological systems change and shape the planet and provide resources. Students also develop an understanding of how Earth processes and human interactions positively and negatively that can change environments impacting the ability for organisms to survive. Student investigations focus on collecting and making sense of observational data and simple measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in fourth grade focus on helping students understand phenomena through systems and system models, energy and matter, and stability and change.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students develop an understanding of how Earth's resources can be transformed into different forms of energy. Students develop a better understanding of electricity and magnetism.

Physical Science Standards	Crosscutting Concepts & Background Information for Educators
4.P4U1.1 Develop and use a model to demonstrate how a system transfers energy from one object to another even when the objects are not touching. **4.P4U1.2** Develop and use a model that explains how energy is moved from place to place through electric currents. **4.P2U1.3** Develop and use a model to demonstrate magnetic forces. **4.P4U3.4** Engage in argument from evidence on the use and impact of renewable and nonrenewable resources to generate electricity.	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity**; Systems and System Models**; **Energy and Matter**; Structure and Function; **Stability and Change**[4] **Background Information:** **Energy** is present whenever there are moving objects, sound**,** light**, or** heat. When objects **collide**, energy can be **transferred** from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. Light also transfers energy from place to place. For example, energy **radiated** from the sun is transferred to Earth by light. When this light is absorbed, it warms Earth's land, air, and water and facilitates plant growth. Energy can also be transferred from place to place by **electric currents**, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy (e.g., moving water driving a spinning turbine which generates electric currents). [4 (p. 125)] The faster a given object is moving, the more energy it possesses. Energy can be moved from place to place by moving objects or through sound **or** light. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.)[4(p.122)] For example, energy radiated from the sun is transferred to Earth by light. When this light is absorbed, it warms Earth's land, air, and water and facilitates plant growth.[4(p.125)] The expression "produce energy" typically refers to the **conversion of stored** energy into a desired form for practical use—for example, the stored energy of water behind a dam is released so that it flows downhill and drives a turbine generator to produce **electricity**. Food and fuel also release energy when they are digested or burned. When machines or animals "use" energy (e.g., to move around), most often the energy is transferred to heat the surrounding environment. The energy released by burning fuel or digesting food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water). (Boundary: The fact that plants capture energy from sunlight is introduced at this grade level, but details of photosynthesis are not.) It is important to be able to **concentrate energy** so that it is available for use where and when it is needed. For example, **batteries** are physically transportable energy **storage** devices, whereas electricity generated by power plants is transferred from place to place through distribution systems. [4 (p. 129)]

Earth and Space Sciences: Students develop an understanding of the different Earth systems and how they interact with each other. They understand how geological systems change and shape Earth and the evidence that is used to understand these changes. They also understand how weather, climate, and human interactions can impact the environment.

Earth and Space Standards	Crosscutting Concepts & Background Information for Educators
4.E1U1.5 **Use models** to explain seismic waves and their effect on the Earth. **4.E1U1.6** **Plan and carry out an investigation** to explore and explain the interactions between Earth's major systems and the impact on Earth's surface materials and processes. **4.E1U1.7** **Develop and/or revise a model** using various rock types, fossil location, and landforms to show evidence that Earth's surface has changed over time. **4.E1U1.8** **Collect, analyze, and interpret data** to explain weather and climate patterns.	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity**; Systems and System Models**; **Energy and Matter**; Structure and Function; **Stability and Change**[4] **Background Information:** **Waves** of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) Earthquakes cause **seismic** waves, which are waves of motion in Earth's crust. Earth's major systems are the **geosphere** (solid and molten rock, soil, and sediments), the **hydrosphere** (water and ice), the **atmosphere** (air), and the **biosphere** (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. The **ocean** supports a variety of ecosystems and organisms, **shapes landforms**, and influences climate. Winds and clouds in the atmosphere interact with the landforms to determine patterns of weather. **Rainfall** helps shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. Human activities affect Earth's systems and their interactions at its surface. [4 (p. 181)] Earth has changed over time. Understanding how landforms develop, are **weathered** (broken down into smaller pieces), and **erode** (get transported elsewhere) can help infer the history of the current landscape. Local, regional, and global patterns of **rock formations** reveal changes over time due to Earth forces, such as **earthquakes**. The presence and location of certain **fossil** types indicate the order in which rock layers were formed. [4 (p. 178)] **Weather** is the minute-by-minute to day-by-day variation of the atmosphere's condition on a local scale. Scientists record the patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. **Climate** describes the ranges of an area's typical weather conditions and the extent to which those conditions vary over years to centuries. [4 (p. 188)]

4.E1U3.9	Crosscutting Concepts & Background Information for Educators
Construct and support an evidence-based argument about the availability of water and its impact on life.	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity**; Systems and System Models**; **Energy and Matter**; Structure and Function; **Stability and Change**[4] **Background Information:** Water is found almost everywhere on Earth: as **vapor**; as **fog** or **clouds** in the **atmosphere**; as **rain** or **snow** falling from clouds; as ice, snow, and running water on land and in the ocean; and as groundwater beneath the surface. The downhill movement of water as it flows to the ocean shapes the appearance of the land. Nearly all of Earth's available water is in the ocean. Most **freshwater** is in glaciers or underground; only a tiny fraction is in streams, lakes, wetlands, and the atmosphere. [4 (p. 185)] A variety of **hazards** result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions, severe weather, floods, coastal erosion). Humans cannot eliminate natural hazards but can take steps to reduce their impacts. [4 (p. 193)]
4.E1U2.10	
Define problem(s) and **design solution(s)** to minimize the effects of natural hazards.	

Life Sciences: Students develop an understanding of the diversity of past and present organisms, factors impacting organism diversity, and evidence of change of organisms over time.

Life Science Standards	Crosscutting Concepts & Background Information for Educators
4.L4U1.11	**Crosscutting Concepts:** Patterns, Cause and Effect, Scale, Proportion and Quantity**; Systems and System Models**; **Energy and Matter**; Structure and Function; **Stability and Change**[4] **Background Information:** When the **environment changes** in ways that affect a place's physical characteristics, **temperature**, or availability of **resources**, some **organisms survive** and **reproduce**, others move to new locations, yet others move into the transformed environment, and some die. [4 (p. 155)] **Fossils** provide evidence about the types of organisms (both visible and microscopic) that lived long ago and also about the nature of their environments. Fossils can be compared with one another and to living organisms according to their similarities and differences. [4 (p. 162)] Changes in an organism's **habitat** are sometimes **beneficial** to it and sometimes **harmful**. For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. [4 (p. 165)]
Analyze and interpret environmental **data** to demonstrate that species either adapt and survive or go extinct over time.	

Fifth Grade: Patterns; Scale, Proportion, and Quantity

By the end of fifth grade, students apply their understanding of scale at macro (time and space) and micro (particles of matter) levels to understand patterns and scale across life, earth and space, and physical sciences. Students will develop an understanding of forces, conservation of matter, and that genetic information can be passed down from parent to offspring. Student investigations focus on collecting and making sense of observational data and measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in fifth grade focus on helping students understand phenomena through patterns and scale, proportion and quantity.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students develop an understanding that changes can occur to matter/objects on Earth or in space, but both energy and matter follow the pattern of being conserved during those changes.

Physical Science Standards	Crosscutting Concepts & Background Information for Educators
5.P1U1.1 [**Analyze and interpret data**]() to explain that matter of any type can be subdivided into particles too small to see and, in a closed system, if properties change or chemical reactions occur, the amount of matter stays the same. **5.P1U1.2** [**Plan and carry out investigations**]() to demonstrate that some substances combine to form new substances with different properties and others can be mixed without taking on new properties.	**Crosscutting Concepts:** **Patterns**, Cause and Effect, **Scale, Proportion and Quantity**; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** **Matter** of any type can be subdivided into **particles** that are too small to see, but even then, the matter still exists and can be detected by other means (e.g., by weighing or by its effects on other objects). For example, a model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon; the effects of air on larger particles or objects (e.g., leaves in wind, dust suspended in air); and the appearance of visible scale water droplets in condensation, fog, and, by extension, also in clouds or the contrails of a jet. The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish (e.g., sugar in solution, evaporation in a closed container). Measurements of a variety of properties (e.g., hardness, reflectivity) can be used to identify particular materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) [4 (p. 108)] When two or more different **substances** are **mixed**, a new substance with different **properties** may be formed; such occurrences depend on the substances and the **temperature**. No matter what reaction or change in properties occurs, the total **weight** of the substances does not change. (Boundary: Mass and weight are not distinguished at this grade level.) [4 (pp. 110-111)] Other substances simply **mix** without changing permanently and can often be separated again. At room temperature, some substances are in the **solid** state, some in the **liquid** state and some in the **gas** state. The state of many substances can be changed by **heating** or **cooling** them. The amount of matter does not change when a solid **melts** or a liquid **evaporates**. [2 (p. 20)]

<table>
<tr><th>5.P2U1.3</th><th>Crosscutting Concepts & Background Information for Educators</th></tr>
<tr><td><u>Construct an explanation</u> using evidence to demonstrate that objects can affect other objects even when they are not touching.</td><td><u>Crosscutting Concepts:</u>
Patterns, Cause and Effect, Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

<u>Background Information:</u>
Gravity is the universal attraction between all objects, however large or small, although it is only apparent when one of the objects is very large. This gravitational attraction keeps the planets in orbit around the Sun, the Moon round the Earth and their moons round other planets. On the Earth it results in everything being pulled down towards the center of the Earth. We call this downward attraction the weight of an object.[2] (p. 21) Objects in contact exert forces on each other (friction, elastic pushes and pulls). Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact-for example, magnets push pull at a distance.[4] (117)</td></tr>
<tr><th>5.P3U1.4</th><th>Crosscutting Concepts & Background Information for Educators</th></tr>
<tr><td><u>Obtain, analyze, and communicate evidence</u> of the effects that balanced and unbalanced forces have on the motion of objects.</td><td rowspan="3"><u>Crosscutting Concepts:</u>
Patterns, Cause and Effect, Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

<u>Background Information:</u>
Each force acts on one particular object and has both a strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) The patterns of an object's motion in various situations can be observed and measured; when past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)[4] (p. 115) How quickly an object's motion is changed depends on the force acting and the object's mass. The greater the mass of an object, the longer it takes to speed it up or slow it down, a property of mass described as inertia.[2] (p. 22)</td></tr>
<tr><th>5.P3U2.5</th></tr>
<tr><td><u>Define problems</u> and <u>design solutions</u> pertaining to force and motion.</td></tr>
</table>

5.P4U1.6	Crosscutting Concepts & Background Information for Educators
Analyze and interpret data to determine how and where energy is transferred when objects move.	**Crosscutting Concepts:** **Patterns**, Cause and Effect, **Scale, Proportion and Quantity**; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** The faster a given object is moving, the more energy it possesses. **Energy** can be moved from place to place by moving objects or through sound, light, or electric currents. (Boundary: At this grade level, no attempt is made to give a precise or complete definition of energy.)[4 (p. 122)] Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be **transferred** from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. Light also transfers energy from place to place. For example, energy radiated from the sun is transferred to Earth by light. When this light is absorbed, it warms Earth's land, air, and water and facilitates plant growth. Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy (e.g., moving water driving a spinning turbine which generates electric currents). [4 (p. 125)]

Earth and Space Sciences: Students develop an understanding of the how gravitational forces in space cause observable patterns due to the position of Earth, Sun, Moon, and stars.

Earth and Space Standards	Crosscutting Concepts & Background Information for Educators
5.E2U1.7	
Develop, revise, and use models based on evidence to **construct explanations** about the movement of the Earth and Moon within our solar system.	**Crosscutting Concepts:** **Patterns**, Cause and Effect, **Scale, Proportion and Quantity**; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** The **Earth** moves round the **Sun** taking about a year for one orbit. The **Moon** orbits the Earth taking about four weeks to complete an orbit. The Sun, at the center of the solar system, is the only object in the solar system that is a source of visible light. The Moon reflects light from the Sun and as it moves round the Earth only those parts illuminated by the Sun are seen. The Earth rotates about an **axis** lying **north** to **south** and this motion makes it appear that the Sun, Moon and stars are moving round the Earth. The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause **observable patterns**. Some objects in the solar system can be seen with the naked eye. Planets in the night sky change positions and are not always visible from Earth as they orbit the sun. Stars appear in patterns called constellations, which can be used for navigation and appear to move together across the sky because of Earth's rotation. [4 (p. 176)]
5.E2U1.8	**Crosscutting Concepts & Background Information for Educators**
Obtain, analyze, and communicate evidence to support an explanation that the gravitational force of Earth on objects is directed toward the planet's center.	**Crosscutting Concepts:** **Patterns**, Cause and Effect, **Scale, Proportion and Quantity**; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** **Gravity** is the universal attraction between all objects, however large or small, although it is only apparent when one of the objects is very large. On the Earth it results in everything being pulled down towards the center of the Earth. We call this downward attraction the **weight** of an object. [2 (p. 21)] The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. [4 (p. 117)]

Life Sciences: Students develop an understanding of patterns and how genetic information is passed from generation to generation. They also develop the understanding of how genetic information and environmental features impact the survival of an organism.

Life Science Standards	Crosscutting Concepts & Background Information for Educators
5.L3U1.9 **Obtain, evaluate, and communicate information** about patterns between the offspring of plants, and the offspring of animals (including humans); **construct an explanation** of how genetic information is passed from one generation to the next. **5.L3U1.10** **Construct an explanation** based on evidence that the changes in an environment can affect the development of the traits in a population of organisms.	**Crosscutting Concepts:** **Patterns**, Cause and Effect, **Scale, Proportion and Quantity**; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** Many **characteristics** of **organisms** are **inherited** from their parents. Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. [4](p. 158) The environment also affects the traits that an organism develops—differences in where they grow or in the food they consume may cause organisms that are related to end up looking or behaving differently. [4](p. 158) When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. [4](p. 155) Offspring acquire a mix of traits from their biological parents. Different organisms vary in how they look and function because they have different inherited information. In each kind of organism there is variation in the traits themselves, and different kinds of organisms may have different versions of the trait. The environment also affects the traits that an organism develops—differences in where they grow or in the food they consume may cause organisms that are related to end up looking or behaving differently. [4](p. 160)

5.L4U3.11	Crosscutting Concepts & Background Information for Educators
Obtain, evaluate, and communicate evidence about how natural and human-caused changes to habitats or climate can impact populations.	**Crosscutting Concepts:** **Patterns**, Cause and Effect, **Scale, Proportion and Quantity**; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** Changes in an organism's **habitat** are sometimes beneficial to it and sometimes harmful. For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.[4 (p. 165)] Scientists have identified and classified many plants and animals. Populations of organisms live in a variety of habitats and change in those habitats affects the organisms living there. Humans, like all other organisms, obtain living and nonliving resources from their environments. [4 (p. 165)]
5.L4U3.12	**Crosscutting Concepts & Background Information for Educators**
Construct an argument based on evidence that inherited characteristics can be affected by behavior and/or environmental conditions.	**Crosscutting Concepts:** Patterns, Cause and Effect, **Scale, Proportion and Quantity**; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** Sometimes the differences in **characteristics** between individuals of the same **species** provide advantages in surviving, finding **mates**, and **reproducing.** Many characteristics of organisms are inherited from their parents. Other characteristics result from individuals' **interactions with the environment**, which can range from diet to learning. Many characteristics involve both inheritance and environment. [4 (p. 158)]

Distribution of Grades 3-5 Standards

	U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	U2: The knowledge produced by science is used in engineering and technologies to create products.	U3: Applications of science often have both positive and negative ethical, social, economic, and political implications.
P1: All matter in the Universe is made of very small particles.	5.P1U1.1 5.P1U1.2		
P2: Objects can affect other objects at a distance.	3.P2U1.1 3.P2U1.2 4.P2U1.3 5.P2U1.3		
P3: Changing the movement of an object requires a net force to be acting on it.	5.P3U1.4	5.P3U2.5	
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.	3.P4U1.3 4.P4U1.1 4.P4U1.2 5.P4U1.6		4.P4U3.4
E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.	3.E1U1.4 4.E1U1.5 4.E1U1.6 4.E1U1.7 4.E1U1.8	4.E1U2.10	4.E1U3.9
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.	5.E2U1.7 5.E2U1.8		
L1: Organisms are organized on a cellular basis and have a finite life span.	3.L1U1.5		
L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.	3.L2U1.6 3.L2U1.7 3.L2U1.8		
L3: Genetic information is passed down from one generation of organisms to another.	5.L3U1.9 5.L3U1.10		
L4: The unity and diversity of organisms, living and extinct, is the result of evolution.	4.L4U1.11		5.L4U3.11 5.L4U3.12

Grades 6-8 Science Standards

The Grades 6-8 Science Standards are designed to provide opportunities for students to develop an understanding of all thirteen core ideas (see Appendix 3) across the 6-8 grade band. To sufficiently demonstrate knowledge, understanding, and performance of each standard, not every core idea is included in every grade.

Within each grade level, students engage in multiple science and engineering practices as they gather information to answer their questions or solve design problems by reasoning how the data provide evidence to support their understanding, and then communicate their understanding of phenomena in physical, earth and space, and life science (the knowing of science). Students apply their knowledge of the core ideas to understand phenomena, see the impact, or construct technological solutions (using science). The crosscutting concepts support their understanding of patterns, cause and effect relationships, and systems thinking as students make sense of phenomena in the natural and designed worlds. The practices, core ideas, and crosscutting concepts help students develop an understanding of skills and knowledge in order to transfer them from one grade to the next and between content areas.

- In sixth grade, students apply their understanding of the cycling of matter, energy flow, and scale, as it relates to molecules, geosphere, the solar system, and ecosystems.
- In seventh grade, students will investigate the relationship between forces and the changes in motion, how energy transfer impacts geologic and atmospheric processes, and the structure and function of cells.
- In eighth grade, students will describe how cause-and-effect interact with stability and change to influence the natural world.

The organization of the standards within this document does not indicate instructional sequence or importance. Decisions about curriculum and instruction are made locally by individual school districts and classroom teachers; these standards can be sequenced, combined, or integrated with other content areas to best meet the local curriculum or student needs (See Appendices 4 and 5). It is suggested to use the metric system for measurement, as most scientific tools utilize the metric system.

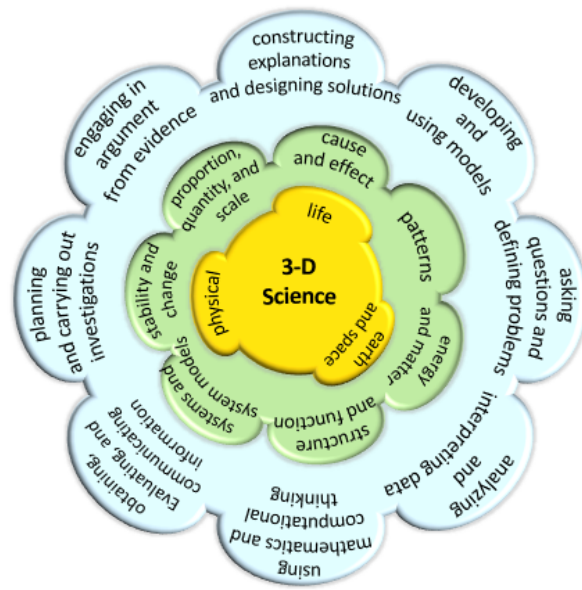


Figure 1: Three Dimensions of Science Instruction

Sixth Grade: Focus on Patterns; Scale, Proportion, and Quantity; Systems and System Models; Energy and Matter

By the end of sixth grade, students apply their understanding of how matter and energy relate to atoms, the solar system, and ecosystems. Students will develop an understanding of the nature of matter and the role of energy transformation. Students will also deepen their understanding of scales, patterns, and properties of matter, the solar system, and ecosystems. Student investigations focus on collecting and making sense of observational data and measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in sixth grade focus on helping students understand phenomena through patterns; scale, proportion, and quantity; systems and system models; and energy and matter.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students develop an understanding of forces and energy and how energy can transfer from one object to another or be converted from one form to another. They also develop an understanding of the nature of matter.

Physical Science Standards	Crosscutting Concepts and Background Information for Educators
6.P1U1.1 **Analyze and interpret data** to show that changes in states of matter are caused by different rates of movement of atoms in solids, liquids, and gases (Kinetic Theory). **6.P1U1.2** **Plan and carry out an investigation** to demonstrate that variations in temperature and/or pressure affect changes in state of matter. **6.P1U1.3** **Develop and use models** to represent that matter is made up of smaller particles called atoms.	**Crosscutting Concepts:** **Patterns**; Cause and Effect; **Scale, Proportion and Quantity**; **Systems and System Models; Energy and Matter;** Structure and Function; Stability and Change[4] **Background Information:** If a **substance** could be divided into smaller and smaller pieces it would be found to be made of very, very small **particles**, smaller than can be seen even with a **microscope**. These particles are not in a substance; they are the substance. All the particles of a particular substance are the same and different from those of other substances. The particles are not static but move in random directions. The **speed** at which they move is experienced as the temperature of the material. The differences between substances in the **solid**, **liquid** or **gas** state can be explained in terms of the speed and range of the movement of particles and the separation and strength of the attraction between neighboring particles. All materials, anywhere in the universe, living and non-living, are made of a very large number of basic 'building blocks' called **atoms**, of which there are about 100 different kinds. The properties of different materials can be explained in terms of the behavior of the atoms and groups of atoms of which they are made. [2 (p. 20)] Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with each other; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and vibrate in position but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (Boundary: Predictions here are qualitative, not quantitative.)[4 (p. 108)]

6.P2U1.4	
Develop and use a model to predict how forces act on objects at a distance.	**Crosscutting Concepts:** **Patterns**; Cause and Effect; **Scale, Proportion and Quantity**; **Systems and System Models; Energy and Matter;** Structure and Function; Stability and Change[4] **Background Information:** **Gravity** is the universal attraction between all objects, however large or small, although it is only apparent when one of the objects is very large. This gravitational attraction keeps the planets in **orbit** around the **Sun**, the **Moon** round the **Earth** and their moons round other planets. The effect of gravity on an object on the Moon is less than that on Earth because the Moon has less mass than the Earth, so a person on the Moon **weighs** less than on Earth even though their mass is the same. The pull of the Earth on the Moon keeps it orbiting the Earth while the pull of the Moon on the Earth gives rise to **tides**. [2 (p. 21)] 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—for example, Earth and the sun. 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. 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).[4 (p. 118)]
6.P4U2.5	**Crosscutting Concepts and Background Information for Educators**
Analyze how humans use technology to store (potential) and/or use (kinetic) energy.	**Crosscutting Concepts:** **Patterns**; Cause and Effect; **Scale, Proportion and Quantity**; **Systems and System Models; Energy and Matter;** Structure and Function; Stability and Change[4] **Background Information:** The **chemicals** in the cells of a battery store energy which is released when the battery is connected so that an electric current flows, **transferring energy** to other components in the circuit and on to the environment. [2 (p. 23)] **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 system of objects may also contain **stored (potential) energy**, depending on their relative positions. [4 (p. 123)]

Earth and Space Sciences: Students develop an understanding of the scale and properties of objects in the solar system and how forces (gravity) and energy cause observable patterns in the Sun-Earth-Moon system.

Earth and Space Standards	Crosscutting Concepts and Background Information for Educators
6.E1U1.6	**<u>Crosscutting Concepts:</u>** **Patterns**; Cause and Effect; **Scale, Proportion and Quantity**; **Systems and System Models; Energy and Matter;** Structure and Function; Stability and Change[4] **<u>Background Information:</u>** The layer of air at the **Earth's** surface is **transparent** to most of the **radiation** coming from the **Sun**, which passes through. The radiation that is absorbed at its surface is the Earth's external source of energy. The radiation from the Sun absorbed by the Earth warms the surface which then emits radiation of longer **wavelength** (**infrared**) that does not pass through the atmosphere but is absorbed by it, keeping the Earth warm. This is called the **greenhouse effect** because it is similar to the way the inside of a greenhouse is heated by the Sun. [2] (p. 24) 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 it habitable.[4] (p. 188)
Investigate and construct an explanation demonstrating that radiation from the Sun provides energy and is absorbed to warm the Earth's surface and atmosphere.	
6.E2U1.7	**Crosscutting Concepts and Background Information for Educators**
Use ratios and proportions to **analyze and interpret data** related to scale, properties, and relationships among objects in our solar system.	**<u>Crosscutting Concepts:</u>** **Patterns**; Cause and Effect; **Scale, Proportion and Quantity**; **Systems and System Models; Energy and Matter;** Structure and Function; Stability and Change[4] **<u>Background Information:</u>** The **Earth** rotates about an **axis** lying north to south and this motion makes it appear that the **Sun**, **Moon** and **stars** are moving round the Earth. This **rotation** causes day and night as parts of the Earth's surface turn to face towards or away from the Sun. It takes a year for the Earth to pass round the Sun. The Earth's axis is tilted relative to the plane of its orbit around the Sun so that the length of day varies with position on the Earth's surface and time of the year, giving rise to the **seasons**. The Earth is one of eight (so far known) planets in our solar system which, along with many other smaller bodies, **orbit** the Sun, in roughly circular paths, at different distances from the Sun and taking different times to complete an orbit. The distances between these bodies are huge – Neptune is 4.5 billion **km** from the Sun, 30 times further than Earth. As seen from Earth, planets move in relation to the positions of the stars which appear fixed relative to each other.[2] (p. 25) The **solar system**
6.E2U1.8	
Develop and use models to explain how constellations and other night sky patterns appear to move due to Earth's rotation and revolution.	

6.E2U1.9	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 model of the solar system can explain **tides**, **eclipses** of the sun and the moon, and the motion of the planets in the sky relative to the **stars**. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. [4] (p. 176)
Develop and use models to construct an explanation of how eclipses, moon phases, and tides occur within the Sun-Earth-Moon system.	
6.E2U1.10	
Use a model to show how the tilt of Earth's axis causes variations in the length of the day and gives rise to seasons.	

Life Sciences: Students develop an understanding of how energy from the Sun is transferred through ecosystems.

Life Science Standards	Crosscutting Concepts and Background Information for Educators
6.L2U3.11	**Crosscutting Concepts:** **Patterns**; Cause and Effect; **Scale, Proportion and Quantity**; **Systems and System Models; Energy and Matter;** Structure and Function; Stability and Change[4] **Background Information:** **Interdependent organisms** living together in particular environmental conditions form an **ecosystem**. In a stable ecosystem there are **producers** of food (plants), **consumers** (animals) and **decomposers**, (bacteria and fungi which feed on waste products and dead organisms). The decomposers produce materials that help plants to grow, so the molecules in the organisms are constantly re-used. At the same time, **energy** resources pass through the ecosystem. When **food** is used by organisms for **life processes** some energy is **dissipated** as **heat** but is replaced in the ecosystem by **radiation** from the **Sun** being used to produce plant food. In any given ecosystem there is **competition** among species for the energy resources and the materials they need to live. The persistence of an ecosystem depends on the continued availability in the environment of these energy resources and materials. **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
Use evidence to construct an argument regarding the impact of human activities on the environment and how they positively and negatively affect the competition for energy and resources in ecosystems.	
6.L2U3.12	
Engage in argument from evidence to support a claim about the factors that cause species to change and how humans can impact those factors.	
6.L2U1.13	
Develop and use models to demonstrate the interdependence of organisms and their environment including biotic and abiotic factors.	

6.L2U1.14	their growth and reproduction. 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.[4] A healthy ecosystem is one in which multiple **species** of different types are each able to meet their needs in a relatively stable web of life. Newly **introduced species** can damage the balance of an ecosystem. [4 (p. 152)] Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of many other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. [4 (p. 196)]
Construct a model that shows the cycling of matter and flow of energy in ecosystems.	

Seventh Grade: Focus on Patterns; Cause and Effect; Structure and Function

By the end of seventh grade, students will explore how forces cause changes in motion and how energy is transferred in geologic, atmospheric, and environmental processes. Students investigate force and motion in a wide variety of systems, model how heat energy drives cycles in weather and climate and

explain the structure and function of cells. Student investigations focus on collecting and making sense of observational data and measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in seventh grade focus on helping students understand phenomena though patterns, cause and effect, and structure and function.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students will explore how cause and effect take place within and between a wide variety of force and motion systems from forces on individual objects to the forces that shape our Earth.

Physical Science Standards	Crosscutting Concepts and Background Information for Educators
7.P2U1.1 **Collect and analyze data** demonstrating how electromagnetic forces can be attractive or repulsive and can vary in strength. **7.P2U1.2** **Develop and use a model** to predict how forces act on objects at a distance. **7.P3U1.3** **Plan and carry out an investigation** that can support an **evidence-based explanation** of how objects on Earth are affected by gravitational force.	**Crosscutting Concepts:** **Patterns; Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** **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. 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**—for example, Earth and the sun. 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. 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).[4 (pp. 117-118)] On Earth, it [**gravity**] results in everything being pulled down towards the center of the Earth. We call this downward **attraction** the **weight** of an object. The object pulls the Earth as much as the Earth pulls the object, but because the Earth's mass is much bigger, we observe the resulting motion of the object, not of the Earth.[2 (p. 21)]
7.P3U1.4	**Crosscutting Concepts and Background Information for Educators**
Use non-algebraic **mathematics and computational thinking** to explain Newton's laws of motion.	**Crosscutting Concepts:** **Patterns**; Cause and Effect; **Scale, Proportion and Quantity**; **Systems and System Models; Energy and Matter;** Structure and Function; Stability and Change[4] **Background Information:** 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. 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. 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. Forces on an object can also change its **shape or orientation**. 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. [4 (pp. 115-116)]

Earth and Space Sciences: Students develop an understanding of the patterns of energy flow along with matter cycling within and among Earth's systems.

Earth and Space Standards	Crosscutting Concepts and Background Information for Educators
7.E1U1.5	
Construct a model that shows the cycling of matter and flow of energy in the atmosphere, hydrosphere, and geosphere.	**Crosscutting Concepts:** **Patterns; Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** **Earth processes** are the result of **energy** flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce **chemical and physical changes** in Earth's materials and living organisms.[4(p.181)] Radioactive decay of material inside the Earth since it was formed is its internal source of energy. Radiation from the Sun provides the energy that enables plants containing chlorophyll to make glucose through the process of photosynthesis.[2 (p. 24)] The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. **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 it habitable.[4 (p. 188)]
7.E1U1.6	**Crosscutting Concepts and Background Information for Educators**
Construct a model to explain how the distribution of fossils and rocks, continental shapes, and seafloor structures provides evidence of the past plate motions.	**Crosscutting Concepts:** **Patterns; Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** **Plate tectonics** is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geological history. Plate movements are responsible for most **continental** and **ocean** floor features and for the distribution of most **rocks** and **minerals** within **Earth's crust**. 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. [4 (p. 183)]

7.E1U2.7	Crosscutting Concepts and Background Information for Educators
Analyze and interpret data to construct an explanation for how advances in technology has improved weather prediction.	**Crosscutting Concepts:** **Patterns; Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** **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. Because these patterns are so complex, weather can be predicted only probabilistically.[4 (p. 188)] Some natural hazards, are preceded by phenomena that allow for reliable predictions. Mapping the history of natural hazards in a region, combined with an understanding of related geological forces can help forecast the locations and likelihoods of future events.[4 (p. 194)]

Life Sciences: Students develop an understanding of the structure and function of cells.

Life Science Standards	Crosscutting Concepts and Background Information for Educators
7.L1U1.8 **Obtain, evaluate, and communicate information** to provide evidence that all living things are made of cells, cells come from existing cells, and cells are the basic structural and functional unit of all living things. **7.L1U1.9** **Construct an explanation** to demonstrate the relationship between major cell structures and cell functions (plant and animal). **7.L1U1.10** **Develop and use a model** to explain how cells, tissues, and organ systems maintain life (animals).	**Crosscutting Concepts:** **Patterns; Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** All living organisms are made of one or more **cells**, which can be seen only through a microscope. All the basic processes of life are the results of what happens inside cells. Cells divide to replace aging cells and to make more cells in growth and in reproduction. Food is the energy source they need in order to carry out these and other functions.[2 (p. 26)] Life is the quality that distinguishes living things - composed of living cells, from nonliving objects or those that have died. While a simple definition of life can be difficult to capture, all living things - that is to say all organisms -can be characterized by common aspects of their structure and functioning.[4 (p.143)] Some cells in **multicellular organisms**, as well as carrying out the **functions** that all cells do, are **specialized**; for example, muscle, blood and nerve cells carry out specific functions within the organism. Cells are often aggregated into tissues, tissues into organs, and organs into **organ systems**. In the human body, systems carry out such key functions as respiration, digestion, elimination of waste and temperature control. The circulatory system takes material needed by cells to all parts of the body and removes soluble waste to the urinary system. Stem cells, which are not specialized, are capable of repairing tissues by being programmed for different functions. Cells function best in certain conditions. Both single cell and multi-cellular organisms have mechanisms to maintain temperature and acidity within certain limits that enable the organism to survive.[2 (p. 26)] Organisms are complex, organized and built on a hierarchical foundation of elements and atoms, to cells and systems of individual organisms to

7.L1U1.11	species and populations living and interacting in complex ecosystems. Organisms range in composition from a **single cell** (unicellular microorganisms) to multicellular organisms, in which different groups of large number of cells work together to form **systems of tissues and organs** (e.g. circulatory, respiratory, nervous, musculoskeletal), that are specialized for particular functions. Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (Boundary: At this grade level, only a few major cell structures should be introduced.)[4] (p. 144) Organisms respond to **stimuli** from their environment and actively maintain their internal environment through **homeostasis**.[4] (p. 143) Plant species have **adaptations** to obtain the water, light, minerals and space they need to grow and reproduce in particular locations characterized by climatic, geological and hydrological conditions. [2] (p. 27)
Construct an explanation for how organisms maintain internal stability and evaluate the effect of the external factors on organisms' internal stability.	
7.L2U1.12	**Crosscutting Concepts and Background Information for Educators**
Construct an explanation for how some plant cells convert light energy into food energy.	**Crosscutting Concepts:** **Patterns; Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; **Structure and Function**; Stability and Change[4] **Background Information:** In most cases, the energy needed for life is ultimately derived from the sun through **photosynthesis** (although in some ecologically important cases, energy is derived from reactions involving inorganic chemicals in the absence of sunlight e.g. chemosynthesis). Plants, algae (including phytoplankton), and other energy-fixing microorganisms use sunlight, water and carbon dioxide to facilitate photosynthesis, which stores energy, forms plant matter, releases oxygen, and maintains plants' activities.[4] (p. 147)

Eighth Grade: Focus on Cause and Effect; Energy and Matter; Stability and Change

By the end of eighth grade, students will describe how stability and change and the process of cause and effect influence changes in the natural world. Students will apply energy principles to chemical reactions, explore changes within Earth and understand how genetic information is passed down to produce variation among the populations. Student investigations focus on collecting and making sense of observational data and measurements using the science and engineering practices: ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in eighth-grade focus on helping students understand phenomena through cause and effect, energy and matter, and stability and change.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Physical Sciences: Students apply stability and change to explore chemical properties of matter and chemical reactions to further understand energy and matter.

Physical Science Standards	Crosscutting Concepts and Background Information for Educators
8.P1U1.1 **Develop and use a model** to demonstrate that atoms and molecules can be combined or rearranged in chemical reactions to form new compounds with the total number of each type of atom conserved. **8.P1U1.2** **Obtain and evaluate information** regarding how scientists identify substances based on unique physical and chemical properties.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4] **Background Information:** All materials, anywhere in the universe, living and non-living, are made of a very large numbers of basic 'building blocks' called **atoms**, of which there are about 100 different kinds. **Substances** made of only one kind of atom are called **elements**. Atoms of different elements can combine together to form a very large number of **compounds**. A **chemical reaction** involves a rearrangement of the atoms in the reacting substances to form new substances, while the total amount of matter remains the same. The properties of different materials can be explained in terms of the behavior of the atoms and groups of atoms of which they are made. [2 (p. 20)] 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. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others store energy. [4 (p. 111)]
8.P4U1.3	**Crosscutting Concepts and Background Information for Educators**
Construct an explanation on how energy can be transferred from one energy store to another. **8.P4U1.4** **Develop and use mathematical models** to explain wave characteristics and interactions. **8.P4U2.5** **Develop a solution** to increase efficiency when transferring energy from one source to another.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4] **Background Information:** Objects can have stored energy (that is, the ability to make things change) either because of their chemical composition (as in fuels and batteries), their movement, their temperature, their position in a gravitational or other field, or because of compression or distortion of an elastic material. [2 (p. 23)] **Energy** can be stored by lifting an object higher above the ground. When it is released and falls, this energy is stored in its **motion**. When an object is heated it has more energy than when it is cold. An object at a higher temperature heats the surroundings or cooler objects in contact with it until they are all at the same temperature. How quickly this happens depends on the kind of material which is heated and on the materials between them (the extent to which they are **thermal insulators** or **conductors**). The chemicals in the cells of a **battery** store energy which is released when the battery is connected so that an **electric current** flows, **transferring energy** to other components in the **circuit** and on to the environment. Energy can be transferred by **radiation**, as sound in air or light in air or a **vacuum**. Many processes and phenomena are described in terms of

	energy exchanges, from the growth of plants to the weather. The transfer of energy in making things happen almost always results in some energy being shared more widely, heating more **atoms** and **molecules** and spreading out by conduction or radiation. The process cannot be reversed and the energy of the random movement of particles cannot as easily be used. Thus, some energy is **dissipated**.[2] (p. 23) A simple wave has a repeating pattern with a specific **wavelength, frequency, and amplitude**. [4] (p. 132)

Earth and Space Sciences: Students explore natural and human-induced cause-and-effect changes in Earth systems over time.

Earth and Space Standards	Crosscutting Concepts and Background Information for Educators
8.E1U1.6 **Analyze and interpret data** about the Earth's geological column to **communicate** relative ages of rock layers and fossils. **8.E1U3.7** **Obtain, evaluate, and communicate** information about data and historical patterns to predict natural hazards and other geological events**.** **8.E1U3.8** **Construct and support an argument** about how human consumption of limited resources impacts the biosphere.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4] **Background Information:** **Plate tectonics** is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geological history. Plate movements are responsible for most **continental** and **ocean floor features** and for the distribution of most **rocks** and **minerals** within Earth's **crust**. 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. [4] (p. 183) Some **natural hazards** are preceded by geological activities that allow for **reliable predictions**; others occur suddenly, with no notice, and are not yet predictable. By tracking the upward movement of magma, for example, volcanic eruptions can often be predicted with enough advance warning to allow neighboring regions to be evacuated. Earthquakes, in contrast, occur suddenly; the specific time, day, or year cannot be predicted. However, the history of earthquakes in a region and the mapping of fault lines can help forecast the likelihood of future events. Finally, satellite monitoring of weather patterns, along with measurements from land, sea, and air, usually can identify developing severe weather and lead to its reliable forecast. [4] (p. 193) **Evolution** is shaped by Earth's varying geological conditions. Sudden changes in conditions (e.g., **meteor impacts, major volcanic eruptions**) have caused **mass extinctions**, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. The evolution and proliferation of living things over geological 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**. [4] (p. 190) Human activities have significantly altered the **biosphere**, sometimes damaging or destroying natural **habitats** and causing **extinction** of many other species. But changes to Earth's environment can have different impacts (negative and positive) for different living things. Typically, as human populations and **per-capita consumption** of **natural resources** increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Life Sciences: Students develop an understanding of patterns and how genetic information is passed from generation to generation. They also develop the understanding of how traits within populations change over time.

Life Science Standards	Crosscutting Concepts and Background Information for Educators
8.L3U1.9 **Construct an explanation** of how genetic variations occur in offspring through the inheritance of traits or through mutations. **8.L3U3.10** **Communicate** how advancements in technology have furthered the field of genetic research and use **evidence to support an argument** about the positive and negative effects of genetic research on human lives.	**Crosscutting Concepts:** Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4] **Background Information:** **Genes** are located in the **chromosomes** of **cells**, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of a specific **protein**, 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). Changes (**mutations**) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. **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. (Boundary: The stress here is on the impact of gene transmission in reproduction, not the mechanism.) [4 (pp. 158-159)] 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. 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**. [4 (p. 160)]

<table>
<tr><th>8.L4U1.11</th><th>Crosscutting Concepts and Background Information for Educators</th></tr>
<tr><td>Develop and use a model to explain how natural selection may lead to increases and decreases of specific traits in populations over time.</td><td rowspan="4"><u>Crosscutting Concepts:</u>
Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

<u>Background Information:</u>
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. 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. [4] (p. 164) Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. 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. 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 become separate species. [4] (p. 165) 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). 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. [4] (p. 167)</td></tr>
<tr><th>8.L4U1.12</th></tr>
<tr><td>Gather and communicate evidence on how the process of natural selection provides an explanation of how new species can evolve.</td></tr>
</table>

Distribution of the Grades 6-8 Standards	U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	U2: The knowledge produced by science is used in engineering and technologies to create products.	U3: Applications of science often have both positive and negative ethical, social, economic, and political implications.
P1: All matter in the Universe is made of very small particles.	6.P1U1.1 8.P1U1.1 6.P1U1.2 8.P1U1.2 6.P1U1.3		
P2: Objects can affect other objects at a distance.	6.P2U1.4 7.P2U1.2 7.P2U1.1		
P3: Changing the movement of an object requires a net force to be acting on it.	7.P3U1.3 7.P3U1.4		
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.	8.P4U1.3 8.P4U1.4	6.P4U2.5 8.P4U2.5	
E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.	6.E1U1.6 7.E1U1.6 7.E1U1.5 8.E1U1.6	7.E1U2.7	8.E1U3.7 8.E1U3.8
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.	6.E2U1.7 6.E2U1.9 6.E2U1.8 6.E2U1.10		
L1: Organisms are organized on a cellular basis and have a finite life span.	7.L1U1.8 7.L1U1.10 7.L1U1.9 7.L1U1.11		
L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.	6.L2U1.13 7.L2U1.12 6.L2U1.14		6.L2U3.11 6.L2U3.12
L3: Genetic information is passed down from one generation of organisms to another.	8.L3U1.9		8.L3U3.10
L4: The unity and diversity of organisms, living and extinct, is the result of evolution.	8.L4U1.11 8.L4U1.12		

High School Science Standards

In Arizona, students are required to take 3 credits of high school science to meet graduation requirements, but there is no mandatory course sequence across the state. Because of this, the high school standards are written at two levels: essential and plus.

- All high school essential standards (HS) should be learned by every high school student regardless of the 3-credit course sequence they take. The full set of high school (HS) essential standards should be taught over that 3-year period. Essential High School Science Standards are designed to provide opportunities for students to develop understanding of all 14 core ideas (see page 4) across three credits of high school science.
- The High School Plus (HS+) standards are designed to enhance the rigor of general science courses by extending the essential standards within chemistry (HS+C), physics (HS+Phy), earth and space sciences (HS+E), or biology (HS+B) to prepare students for entry level college courses.

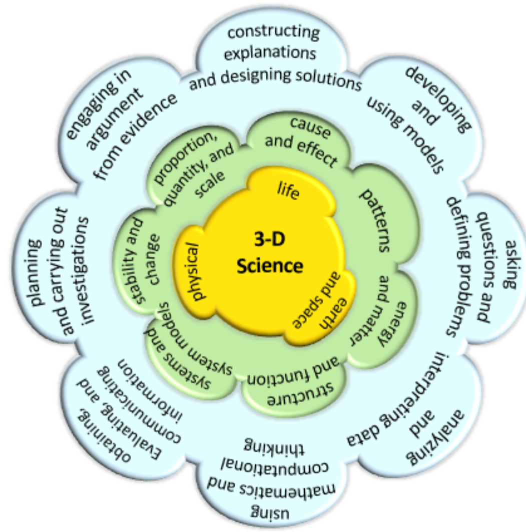


Figure 1: Three Dimensions of Science Instruction

Throughout grades K through 8, students are engaged in multiple science and engineering practices as they gather information to answer their questions or solve design problems, reason about how the data provide evidence to support their understanding, and then communicate their understanding of phenomena in physical, earth and space, and life science (knowing science). The High School standards continue this pattern, and educators should seek ways to integrate the science and engineering practices, as students apply their knowledge of core ideas to understand how scientists continue to build an understanding of phenomena and see how people are impacted by natural phenomena or to construct solutions (using science). The crosscutting concepts support their understanding of patterns, cause and effect relationships, and systems thinking as students make sense of phenomena in the natural and designed worlds. In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline such as the international system of units, scientific notation, conversion factors, and significant figures, as well as the importance of scientific research and peer review. It is suggested to use the metric system for measurement, as most scientific tools utilize the metric system. The organization of the standards within this document does not indicate instructional sequence or importance. Decisions about curriculum and instruction are made locally by individual school districts and classroom teachers; these standards can be sequenced, combined, or integrated with other content areas to best meet the local curriculum or student needs (See Appendices 4 and 5). Suggestions for learning progressions, key terms, crosscutting concepts, and connections to other content area standards are included to assist teachers when implementing the Science Standards and are not intended to be the minimum or maximum content limits.

High School Physical Sciences

Physical science encompasses physical and chemical sub-processes that occur within systems. At the high school level, students gain an understanding of these processes at both the micro and macro levels through the intensive study of matter, energy, and forces.[4] Students are expected to apply these concepts to real-world phenomena to gain a deeper understanding of causes, effects, and solutions for physical processes in the real world. The essential standards are those that every high school student is expected to know and understand. Plus standards in chemistry and physics are designed to extend the concepts learned in the essential standards to prepare students for entry level college courses. It is suggested to use the metric system within measurement.

Note:

- The standard number is designed for recording purposes and does not imply instructional sequence or importance.
- In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Chemistry – P1: All matter in the Universe is made of very small particles.

Structures and Properties of Matter

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.P1U1.1 Develop and use models to explain the relationship of the structure of atoms to patterns and properties observed within the Periodic Table and describe how these models are revised with new evidence.	**Crosscutting Concepts & Background Information for Educators** **Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** Each **atom** has a charged substructure consisting of a **nucleus**, which is made of **protons** and **neutrons**, surrounded by **electrons**. The **periodic table** orders elements horizontally by the number of protons in the atom's nucleus and places those with similar **chemical properties** in columns. The repeating patterns of this table reflect patterns of **outer electron states**. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **Stable** forms of matter are those in which the electric and magnetic field energy is minimized. [4 (p. 109)] Atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities. [4 (p. 134)]
Physical Science Plus (+) Standards HS+C are supporting standards designed to be used with the essential standards for students taking a high school chemistry (C) course.	
Plus HS+C.P1U1.1 Develop and use models to demonstrate how changes in the number of subatomic particles (protons, neutrons, electrons) affect the identity, stability, and properties of the element.	
Plus HS+C.P1U1.2 Obtain, evaluate, and communicate the qualitative evidence supporting claims about how atoms absorb and emit energy in the form of electromagnetic radiation.	
Plus HS+C.P1U1.3 Analyze and interpret data to develop and support an explanation for the relationships between kinetic molecular theory and gas laws.	

Chemistry – P1: All matter in the Universe is made of very small particles. **Chemical Reactions** Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.	
Essential HS.P1U1.2 Develop and use models for the transfer or sharing of electrons to predict the formation of ions, molecules, and compounds in both natural and synthetic processes. **Essential HS.P1U1.3** Ask questions, plan, and carry out investigations to explore the cause and effect relationship between reaction rate factors. Physical Science Plus (+) Standards HS+C are supporting standards designed to be used with the essential standards for students taking a high school chemistry (C) course. **Plus HS+C.P1U1.4** Develop and use models to predict and explain forces within and between molecules. **Plus HS+C.P1U1.5** Plan and carry out investigations to test predictions of the outcomes of various reactions, based on patterns of physical and chemical properties. **Plus HS+C.P1U1.6** Construct an explanation, design a solution, or refine the design of a chemical system in equilibrium to maximize production. **Plus HS+C.P1U1.7** Use mathematics and computational thinking to determine stoichiometric relationships between reactants and products in chemical reactions.	**Crosscutting Concepts & Background Information for Educators** **Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** **Chemical processes**, their **rates**, and whether or not **energy** is **stored** or **released** can be understood in terms of the **collisions** of **molecules** and the rearrangements of **atoms** into new molecules, that are matched by changes in **kinetic energy**. In many situations, a dynamic and condition-dependent balance between a **reaction** and the reverse reaction determines the numbers of all types of molecules present. The fact that atoms are **conserved**, together with knowledge of the **chemical properties** of the elements involved, can be used to describe and predict chemical reactions.[4 (p. 111)]

Chemistry – P1: All matter in the Universe is made of very small particles.

Nuclear Processes and Applications of Chemistry

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.P1U3.4 **Obtain, evaluate, and communicate information** about how the use of chemistry related technologies have had positive and negative ethical, social, economic, and/or political implications. Physical Science Plus (+) Standards HS+C are supporting standards designed to be used with the essential standards for students taking a high school chemistry (C) course. **Plus HS+C.P1U3.8** **Engage in argument from evidence** regarding the ethical, social, economic, and/or political benefits and liabilities of fission, fusion, and radioactive decay.	**Crosscutting Concepts & Background Information for Educators** **Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require **ethical and moral judgements** which are not provided by knowledge of science. There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues. Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion. [2] (p. 33) The total number of neutrons plus protons does not change in any **nuclear process**. Strong and weak nuclear interactions determine nuclear stability and processes. Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present. [4] (p. 113)

Physics – P2: Objects can affect other objects at a distance.

Motion & Stability – Forces & Interactions

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.P2U1.5

Construct an explanation for a field's strength and influence on an object (electric, gravitational, magnetic).

Physical Science Plus (+) Standards HS+P are supporting standards designed to be used with the essential standards for students taking a high school physics (P) course.

Plus HS+Phy.P2U1.1

Plan and carry out investigations to **design, build, and refine a device** that works within given constraints to demonstrate that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

Newton's law of universal gravitation and **Coulomb's law** provide the mathematical models to describe and predict the effects of **gravitational** and **electrostatic forces** between distant objects. Forces at a distance are explained by fields permeating space that can transfer energy through space. **Magnets** or changing electric fields cause **magnetic fields**; **electric charges** or changing magnetic fields cause **electric fields**. [4 (p. 116)]

Some cases of action at a distance are not explained in terms of radiation from a source to a receiver. A magnet, for example, can attract or repel another magnet and both play equal parts. Similarly, the attraction and repulsion between electric charges is reciprocal. The idea of a field is useful for thinking about such situations. A field is the region of the object's influence around it, the strength of the field decreasing with distance from the object. Another object entering this field experiences an effect – attraction or repulsion. Gravity, electric and magnetic interactions can be described in terms of fields.[2 (p. 21)]

Physics – P3: Changing the movement of an object requires a net force to be acting on it.

Motion & Stability – Forces & Interactions

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.P3U1.6

Collect, analyze, and interpret data regarding the change in motion of an object or system in one dimension, to construct an explanation using Newton's Laws.

Physical Science Plus (+) Standards HS+P are supporting standards designed to be used with the essential standards for students taking a high school physics (P) course.

Plus HS+Phy.P3U1.2

Develop and use mathematical **models** of Newton's law of gravitation and Coulomb's law to describe and predict the gravitational and electrostatic forces between objects.

Plus HS+Phy.P3U1.3

Develop a mathematical **model,** using Newton's laws, to predict the motion of an object or system in two dimensions (projectile and circular motion).

Plus HS+Phy.P3U1.4

Engage in argument from evidence regarding the claim that the total momentum of a system is conserved when there is no net force on the system.

Essential HS.P3U2.7

Use mathematics and computational thinking to explain how Newton's laws are used in engineering and technologies to create products to serve human ends.

Plus HS+Phy.P3U2.5

Design, evaluate, and refine a device that minimizes or maximizes the force on a macroscopic object during a collision.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. **Momentum** is defined for a particular frame of reference; it is the **mass** times the **velocity** of the object. In any system, total momentum is always **conserved**. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.[4 (p. 116)] The application of science in making new materials is an example of how scientific knowledge has led advances in technology and provided engineers with a wider choice in designing constructions. At the same time technological advances have helped scientific developments by improving instruments for observation and measuring, automating processes that might otherwise be too dangerous or time consuming to undertake, and particularly through the provision of computers. Thus, **technology aids scientific advances** which in turn can be used in **designing and making things for people to use**. [2 (p. 32)]

Physics – P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.

Energy & Waves

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.P4U1.8
Engage in argument from evidence that the net change of energy in a system is always equal to the total energy exchanged between the system and the surroundings.

Essential HS.P4U3.9
Engage in argument from evidence regarding the ethical, social, economic, and/or political benefits and liabilities of energy usage and transfer.

Physical Science Plus (+) Standards HS+P are supporting standards designed to be used with the essential standards for students taking a high school physics (P) course.

Plus HS+Phy.P4U1.6
Analyze and interpret data to quantitatively describe changes in energy within a system and/or energy flows in and out of a system.

Plus HS+Phy.P4U2.7
Design, evaluate, and refine a device that works within given constraints to transfer energy within a system.

Plus HS+Phy.P4U1.8
Use mathematics and computational thinking to explain the relationships between power, current, voltage, and resistance.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:
Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:
Energy is a quantitative property of a system that depends on the **motion** and interactions of **matter** and **radiation** within that system. That there is a single quantity called energy is due to the fact that a system's total energy is **conserved**, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. At the macroscopic scale, energy manifests itself in multiple ways, such as in **motion**, **sound, light**, and **thermal energy**. "**Mechanical energy**" generally refers to some combination of motion and stored energy in an operating machine. "**Chemical energy**" generally is used to mean the energy that can be released or stored in chemical processes, and "**electrical energy**" may mean energy stored in a **battery** or energy transmitted by **electric currents**. Historically, different **units** and names were used for the energy present in these different phenomena, and it took some time before the relationships between them were recognized. [4 (p. 123)] **Conservation** of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and **transferred** between systems. Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. The availability of energy limits what can occur in any system.[4 (p. 126)] Across the world, the demand for energy increases as human populations grow and because modern lifestyles require more energy, particularly in the convenient form of electrical energy. Fossil fuels, frequently used in power stations and generators, are a limited resource and their combustion contributes to global warming and climate change. Therefore, other ways of generating electricity have to be sought, whilst reducing demand and improving the efficiency of the processes in which we use it. [2 (p. 23)]

Essential HS.P4U1.10	Crosscutting Concepts & Background Information for Educators
Construct an explanation about the relationships among the frequency, wavelength, and speed of waves traveling in various media, and their applications to modern technology.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** The **wavelength** and **frequency** of a wave are related to one another by the **speed** of travel of the wave, which depends on the type of wave and the **medium** through which it is passing. The **reflection, refraction, and transmission** of waves at an interface between two media can be modeled on the basis of these properties. Combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. **Resonance** is a phenomenon in which waves add up in phase in a structure, growing in **amplitude** due to energy input near the natural vibration frequency. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments.[4 (p. 132-133)] All electromagnetic radiation travels through a vacuum at the same speed, called the speed of light. Its speed in any other given medium depends on its wavelength and the properties of that medium. When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. Photovoltaic materials emit electrons when they absorb light of a high-enough frequency. [4 (p. 134)] Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communications, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.) [4 (p. 137)]

High School Earth and Space Sciences

Earth and space science encompass processes that occur on Earth while also addressing Earth's place within our solar system and galaxy. At the high school level, students gain an understanding of these processes through a wide scale: unimaginably large to invisibly small.[1] Earth and Space Sciences, more than any other discipline, are rooted in other scientific disciplines. Students, through the close study of earth and space, will find clear applications for their knowledge of gravitation, energy, magnetics, cycles, and biological processes. Educators should use the "connections" designations within these standards to assist students in making connections between scientific disciplines. Additionally, students are expected to apply these concepts to real-world phenomena to gain a deeper understanding of causes, effects, and solutions for physical processes in the real world. The essential standards are those that every high school student is expected to know and understand. Plus standards in Earth and Space Science are designed to extend the concepts learned in the essential standards to prepare students for entry level college courses.

Note:

- The standard number is designed for recording purposes and does not imply instructional sequence or importance.
- In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Earth and Space – E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Weather & Climate

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Standards	Crosscutting Concepts & Background Information for Educators
Essential HS.E1U1.11 Analyze and interpret data to determine how energy from the Sun affects weather patterns and climate. Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course. **Plus HS+E.E1U1.1** Construct an explanation based on evidence for how the Sun's energy transfers between Earth's systems. **Plus HS+E.E1U1.2** Develop and use models to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. **Plus HS+E.E1U1.3** Analyze geoscience **data** and the results from global climate models to make evidence-based predictions of current rate and scale of global or regional climate changes.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** **Weather**, which varies from day to day and seasonally throughout the year, is the condition of the atmosphere at a given place and time. **Climate** is longer term and location sensitive; it is the range of a region's weather over 1 year or many years, and, because it depends on latitude and geography, it varies from place to place.[4 (186)] The foundation for Earth's global climate system is the **electromagnetic radiation** from the sun as well as its **reflection, absorption, storage, and redistribution** among the **atmosphere, ocean, and land systems** and this energy's reradiation into space. **Climate change** can occur when certain parts of Earth's systems are altered. **Geological evidence** indicates that past climate changes were either sudden changes caused by **alterations in the atmosphere**; **longer term changes** (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even **more gradual atmospheric changes** due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years.[4 (188)]

Earth and Space – E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Roles of Water in Earth's Surface Processes

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.E1U1.12

Develop and use models of the Earth that explains the role of energy and matter in Earth's constantly changing internal and external systems (geosphere, hydrosphere, atmosphere, biosphere).

Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course.

Plus HS+E.E1U1.4

Analyze and interpret geoscience **data** to make the claim that dynamic interactions with Earth's surface can create feedbacks that cause changes to other Earth systems.

Plus HS+E.E1U1.5

Obtain, evaluate, and communicate information on the effect of water on Earth's materials, surface processes, and groundwater systems.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

Earth's systems, being dynamic and interacting, cause **feedback effects** that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts. Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but **solid inner core**, a **liquid outer core**, a **solid mantle** and **crust**. The top part of the mantle, along with the crust, forms structures known as **tectonic plates** (link to ESS2.B). Motions of the mantle and its plates occur primarily through **thermal convection**, which involves the **cycling of matter** due to the outward flow of energy from Earth's interior and the gravitational movement of denser materials toward the interior. The **geological record** shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. [4 (p. 181)]

The **abundance of liquid water** on Earth's surface and its **unique combination of physical and chemical properties** are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks. [4 (pp. 185-186)]

Earth and Space – E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Earth's Systems

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.E1U1.13

Evaluate explanations and theories about the role of energy and matter in geologic changes over time.

Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course.

Plus HS+E.E1U1.6

Obtain, evaluate, and communicate information of the theory of plate tectonics to explain the differences in age, structure, and composition of Earth's crust.

Plus HS+E.E1U1.7

Engage in argument from evidence of ancient Earth materials, meteorites, and other planetary surfaces to explain Earth's formation and early history.

Plus HS+E.E1U1.8

Develop and use models to illustrate how Earth's internal and surface processes operate over time to form, modify, and recycle continental and ocean floor features.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

Radioactive decay lifetimes and **isotopic content** in rocks provide a way of **dating** rock formations and thereby fixing the scale of **geological time**. Continental rocks, which can be older than 4 billion years, are generally much older than rocks on the ocean floor, which are less than 200 million years old. **Tectonic processes** continually generate new ocean seafloor at ridges and destroy old seafloor at trenches. Although active geological processes, such as plate tectonics (link to ESS2.B) and **erosion**, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. [4 (pp. 178-179)] Beneath the Earth's solid crust is a hot layer called the mantle. The mantle is solid when under **pressure** but melts (and is called **magma**) when the pressure is reduced. In some places there are cracks (or thin regions) in the crust which can allow magma to come to the surface, for example in **volcanic eruptions**. The Earth's crust consists of a number of solid plates which move relative to each other, carried along by movements of the mantle. Where plates collide, mountain ranges are formed and there is a **fault line** along the **plate boundary** where earthquakes are likely to occur and there may also be volcanic activity. The Earth's surface changes slowly over time, with mountains being eroded by weather, and new ones produced when the crust is forced upwards. [2 (p. 24)]

Earth and Space – E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.

Earth and Human Activity

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.E1U3.14

Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other.

Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course.

Plus HS+E.E1U3.9

Construct an explanation, based on evidence, for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Plus HS+E.E1U3.10

Ask questions, define problems, and evaluate a solution to a complex problem, based on prioritized criteria and tradeoffs, that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Plus HS+E.E1U3.11

Develop and use a quantitative model to illustrate the relationship among Earth systems and the degree to which those relationships are being modified due to human activity.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

Changes in the atmosphere due to **human activity** have increased **carbon dioxide** concentrations and thus affect climate (link to ESS3.D). [4 (188)] **Global climate models** are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history. Though the magnitudes of humans' impacts are greater than they have ever been, so too are humans' abilities to model, predict, and manage current and future impacts.[4 (198)] Materials important to modern technological societies are not uniformly distributed across the planet (e.g., oil in the Middle East, gold in California). Most elements exist in Earth's crust at concentrations too low to be extracted, but in some locations—where geological processes have concentrated them—**extraction** is economically viable. Historically, humans have populated regions that are climatically, hydrologically, and geologically advantageous for fresh water availability, food production via agriculture, commerce, and other aspects of civilization. **Resource availability** affects geopolitical relationships and can limit development. As the global human population increases and people's demands for better living conditions increase, resources considered readily available in the past, such as land for agriculture or drinkable water, are becoming scarcer and more valued. All forms of resource extraction and land use have associated economic, social, environmental, and geopolitical **costs and risks**, as well as **benefits**. New technologies and regulations can change the balance of these factors. Much energy production today comes from **nonrenewable sources**, such as coal and oil. However, advances in related science and technology are reducing the cost of energy from **renewable resources**, such as sunlight. As a result, future energy supplies are likely to come from a much wider range of sources. [4(191-192)]

Earth and Space – E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Earth's Place in the Universe** Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.	
Essential HS.E2U1.15 **Construct an explanation** **based on evidence** to illustrate the role of nuclear fusion in the life cycle of a star. Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course. **Plus HS+E.E2U1.12** **Obtain, evaluate, and communicate** scientific information about the way stars, throughout their stellar stages, produce elements and energy	**Crosscutting Concepts & Background Information for Educators** **Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** Our Sun is one of many stars that make up the Universe, essentially made of hydrogen. The source of energy that the Sun and all stars radiate comes from **nuclear reactions** in their central cores. The Sun is one of millions of stars that together make up a galaxy called the Milky Way. [2 (p. 25)] Nearly all observable matter in the universe is hydrogen or helium, which formed in the first minutes after the Big Bang. Elements other than these remnants of the Big Bang continue to form within the cores of stars. **Nuclear fusion** within stars produces all atomic nuclei lighter than and including iron, and the process releases the energy seen as starlight. Heavier elements are produced when certain massive stars achieve a **supernova** stage and explode. [4 (p. 173)]

Earth and Space – E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

Earth and the Solar System

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.E2U1.16

Construct an explanation of how gravitational forces impact the evolution of planetary motion, structure, surfaces, atmospheres, moons, and rings.

Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course.

Plus HS+E.E2U1.13

Analyze and interpret data showing how gravitational forces are influenced by mass, and the distance between objects.

Plus HS+E.E2U1.14

Use mathematics and computational thinking to explain the movement of planets and objects in the solar system.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

The solar system consists of the sun and a collection of objects of varying sizes and conditions—including planets and their moons—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**. Earth and the moon, sun, and planets have predictable patterns of movement. These patterns, which are explainable by gravitational forces and conservation laws, in turn explain many large-scale **phenomena** observed on Earth. [4 (p. 176)] Planetary motions around the sun can be predicted **using Kepler's three empirical laws**, which can be explained based on **Newton's theory of gravity.** [4 (p. 175)] Kepler's laws describe common features of the motions of orbiting objects, including their **elliptical** paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system. (Boundary: application of laws rather than memorization should be emphasized.) Gravity holds Earth in orbit around the sun, and it holds the moon in **orbit** around Earth. [4 (p. 176)]

Earth and Space – E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.

The Universe and its Stars

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Standards	Crosscutting Concepts & Background Information for Educators
Essential HS.E2U1.17 **Construct an explanation** of the origin, expansion, and scale of the universe based on astronomical evidence. Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course. **Plus HS+E.E2U1.15** **Obtain, evaluate, and communicate** information on how the nebular theory explains solar system formation with distinct regions characterized by different types of planetary and other bodies. **Plus HS+E.E2U1.16** **Obtain, evaluate, and communicate** information about patterns of size and scale of our solar system, our galaxy, and the universe. **Plus HS+E.E2U2.17** **Obtain, evaluate, and communicate** the impact of technology on human understanding of the formation, scale, and composition of the universe.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** Our Sun is one of many stars that make up the **universe**, essentially made of hydrogen. The source of energy that the Sun and all stars radiate comes from nuclear reactions in their central cores. The Sun is one of millions of stars that together make up a **galaxy** called the **Milky Way**. The next nearest star is much further away than the distance of the furthest planet, Neptune. The distances between and within galaxies are so great that they are measured in 'light years', the distance that light can travel in a year. There are billions of galaxies in the universe, almost unimaginably vast distances apart and perceived as moving rapidly away from each other. This apparent movement of galaxies indicates that the universe is expanding from an event called a 'big bang', about 13.7 billion years ago. [2(p. 25)]

High School Life Sciences

Life science focuses on the patterns, processes, and relationships of living organisms. At the high school level, students apply concepts learned in earlier grades to real-world situations and investigations using the science and engineering practices to fully explore phenomena and to develop solutions to societal problems related to food, energy, health, and environment. The field of life science is rapidly advancing and new technology and information related to the study of life processes is being developed daily. Students in high school should have access to up-to-date information in the field while simultaneously gaining understanding of the historical developments which shaped today's understandings within the field. The standards for life science encompass the areas of cells and organisms; ecosystems, interactions, energy and dynamics; heredity; and biological diversity. Like earth and space sciences and physical sciences, "connections" with the life science standards allow educators to make connections across scientific disciplines. The essential standards are those that every high school student is expected to know and understand. Plus standards in life science are designed to extend the concepts learned in the essential standards to prepare students for entry level college courses.

Note:

- The standard number is designed for recording purposes and does not imply instructional sequence or importance.
- In all disciplines, educators should incorporate scientific measurement skills appropriate to that discipline.

Core Ideas for Knowing Science*		Core Ideas for Using Science*
Physical Science P1: All matter in the Universe is made of very small particles. P2: Objects can affect other objects at a distance. P3: Changing the movement of an object requires a net force to be acting on it. P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event. **Earth and Space Science** E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe. **Life Science** L1: Organisms are organized on a cellular basis and have a finite life span. L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms. L3: Genetic information is passed down from one generation of organisms to another. L4: The unity and diversity of organisms, living and extinct, is the result of evolution.		U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised. U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products. U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.

***Adapted from *Working with Big Ideas in Science Education*[2]**

Life Science – L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms & L4: The unity and diversity of organisms, living and extinct, is the result of evolution.

Ecosystems

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.L2U3.18 **Obtain, evaluate, and communicate** about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem. Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course. **Plus HS+B.L2U1.1** **Develop a model** showing the relationship between limiting factors and carrying capacity, and use the model to make predictions on how environmental changes impact biodiversity. **Plus HS+B.L4U1.2** **Engage in argument from evidence** that changes in environmental conditions or human interventions may change species diversity in an ecosystem.	**Crosscutting Concepts & Background Information for Educators** **Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** A complex set of **interactions** within an **ecosystem** can keep its numbers and types of **organisms** relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and **habitat** availability. Moreover, **anthropogenic changes** (induced by human activity) in the environment —including habitat destruction, **pollution**, introduction of **invasive species**, **overexploitation**, and **climate change** —can disrupt an ecosystem and threaten the survival of some **species.** [4 (pp. 155-156)] Ecosystems have **carrying capacities**, which are **limits** to the numbers of organisms and populations they can support. These limits result from such **factors** as the availability of living and nonliving resources and from such challenges as **predation, competition**, and **disease**. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and **resources are finite**. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. [4 (p. 152)] **Biodiversity** is increased by the formation of new species (**speciation**) and decreased by the loss of species (**extinction**). Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital. Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is having positive and negative impacts on biodiversity through **overpopulation**, **overexploitation**, **habitat destruction, pollution, introduction of invasive species, and climate change**. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. Thus sustaining biodiversity so that **ecosystem** functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. [4 (p. 167)]

Life Science – L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

Ecosystems

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.L2U1.19

Develop and use models that show how changes in the transfer of matter and energy within an ecosystem and interactions between species may affect organisms and their environment.

Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course.

Plus HS+B.L2U1.3

Use mathematics and computational thinking to support claims for the cycling of matter and flow of energy through trophic levels in an ecosystem.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. **Matter and energy are conserved** in each change. This is true of all biological systems, from individual cells to ecosystems. [4 (p. 148)] **Photosynthesis** and **cellular respiration** (including **anaerobic processes**) provide most of the energy for life processes. Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this **inefficiency**, there are generally fewer organisms at higher levels of a food web, and there is a **limit to the number of organisms that an ecosystem can sustain**. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil and are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved; some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. **Competition** among species is ultimately competition for the matter and energy needed for life. [4 (p. 154)]

Life Science – L1: Organisms are organized on a cellular basis and have a finite life span.

Cells & Organisms

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.L1U1.20	Crosscutting Concepts & Background Information for Educators
Ask questions and/or make predictions based on observations and evidence to demonstrate how cellular organization, structure, and function allow organisms to maintain homeostasis.	**Crosscutting Concepts:** Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4] **Background Information:** Within cells there are many molecules of different kinds which interact in carrying out the functions of the cell. In multicellular organisms **cells communicate** with each other by passing substances to nearby cells to coordinate activity. A **membrane** around each cell plays an important part in **regulating what can enter or leave a cell**. Activity within different types of cells is regulated by **enzymes**. [2] (p. 26) Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as **water**, **proteins, carbohydrates, lipids,** and **nucleic acids**. Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. **Feedback mechanisms** maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some **range**. Outside that range (e.g., at a too high or too low external temperature, with too little food or water available), the organism cannot survive. Feedback mechanisms can encourage (through **positive feedback**) or discourage (**negative feedback**) what is going on inside the living system. [4] (p. 145)
Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course.	
Plus HS+B.L1U1.4 **Develop and use models** to explain the interdependency and interactions between cellular organelles.	
Plus HS+B.L1U1.5 **Analyze and interpret data** that demonstrates the relationship between cellular function and the diversity of protein functions.	
Plus HS+B.L1U1.6 **Develop and use models** to show how transport mechanisms function in cells.	
Plus HS+B.L1U1.7 **Develop and use models** to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms (plant and animal).	

Life Science – L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.

Cells & Organisms

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.L2U1.21

Obtain, evaluate, and communicate data showing the relationship of photosynthesis and cellular respiration; flow of energy and cycling of matter.

Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course.

Plus HS+B.L2U1.8

Develop and use models to develop a scientific **explanation** that illustrates how photosynthesis transforms light energy into stored chemical energy and how cellular respiration breaks down macromolecules for use in metabolic processes.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

The process of **photosynthesis** converts **light energy** to **stored chemical energy** by converting **carbon dioxide** plus **water** into **sugars** plus released **oxygen**. The sugar molecules thus formed contain carbon, hydrogen, and oxygen; their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. For example, **aerobic** (in the presence of oxygen) **cellular respiration** is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. **Anaerobic** (without oxygen) cellular respiration follows a different and less efficient chemical pathway to provide energy in cells. Cellular respiration also releases the energy needed to **maintain body temperature** despite ongoing energy loss to the surrounding environment. [4 (p. 148)]

<table>
<tr><td colspan="2">Life Science – L1: Organisms are organized on a cellular basis and have a finite life span.
Cells and Organisms
Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.</td></tr>
<tr><td>Essential HS.L1U1.22
<u>Construct an explanation</u> for how cellular division (mitosis) is the process by which organisms grow and maintain complex, interconnected systems.

Essential HS.L1U3.23
<u>Obtain, evaluate, and communicate</u> the ethical, social, economic and/or political implications of the detection and treatment of abnormal cell function.

Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course.

Plus HS+B.L1U1.9
<u>Develop and use a model</u> to <u>communicate</u> how a cell copies genetic information to make new cells during asexual reproduction (mitosis).</td>
<td>Crosscutting Concepts & Background Information for Educators

<u>Crosscutting Concepts:</u>
Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

<u>Background Information:</u>
In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. [4 (pp. 146-147)]

Given a suitable medium, cells from a variety of organisms can be grown in situ, that is, outside the organism. These cell cultures are used by scientists to investigate cell functions and have medical implications such as the production of vaccines, screening of drugs, and in vitro fertilization. Plant tissue culture is used widely in the plant sciences, forestry, and in horticulture. Most cells are programmed for a limited number of cell divisions. Diseases, which may be caused by invading microorganisms, environmental conditions or defective cell programming, generally result in disturbed cell function. Organisms die if their cells are incapable of further division. [2 (p. 26)]</td></tr>
</table>

Life Science – L3: Genetic information is passed down from one generation of organisms to another. Genetics

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.L3U1.24
Construct an explanation of how the process of sexual reproduction contributes to genetic variation.

Essential HS.L3U1.25
Obtain, evaluate, and communicate information about the causes and implications of DNA mutation.

Essential HS.L3U3.26
Engage in argument from evidence regarding the ethical, social, economic, and/or political implications of a current genetic technology.

Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course.

Plus HS+B.L3U1.10
Use mathematics and computational thinking to explain the variation that occurs through meiosis and calculate the distribution of expressed traits in a population.

Plus HS+B.L3U1.11
Construct an explanation for how the structure of DNA and RNA determine the structure of proteins that perform essential life functions.

Plus HS+B.L3U1.12
Analyze and interpret data on how mutations can lead to increased genetic variation in a population.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:
Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:
In **sexual reproduction**, a specialized type of cell division called **meiosis** occurs and results in the production of sex cells, such as **gametes** (**sperm and eggs**) or **spores**, which contain only one member from each **chromosome pair** in the parent cell. [4 (pp. 147)]

The information passed from parents to offspring is coded in the **DNA** molecules that form the **chromosomes**. In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more **genetic variation**. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in **mutations**, which are also a source of genetic variation. **Environmental factors** can also cause mutations in genes, and viable mutations are inherited. Environmental factors also affect **expression of traits**, and hence affect the **probability** of occurrences of traits in a population. Thus the variation and distribution of traits observed depend on both **genetic and environmental factors**. [4 (p. 147)]

The overall sequence of genes of an organism is known as its **genome**. More is being learned all the time about genetic information by **mapping the genomes** of different kinds of organisms. When sequences of genes are known genetic material can be **artificially changed** to give organisms certain features. In **gene therapy** special techniques are used to deliver into human cells genes that are beginning to help in curing disease. [2 (p. 28)]

Life Science – L4: The unity and diversity of organisms, living and extinct, is the result of evolution.

Evolution

Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.

Essential HS.L4U1.27

Obtain, evaluate, and communicate evidence that describes how changes in frequency of inherited traits in a population can lead to biological diversity.

Essential HS.L4U1.28

Gather, evaluate, and communicate multiple lines of empirical evidence to explain the mechanisms of biological evolution.

Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course.

Plus HS+B.L4U1.13

Obtain, evaluate, and communicate multiple lines of empirical evidence to explain the change in genetic composition of a population over successive generations.

Plus HS+B.L4U1.14

Construct an explanation based on scientific evidence that the process of natural selection can lead to adaption.

Crosscutting Concepts & Background Information for Educators

Crosscutting Concepts:

Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change[4]

Background Information:

Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a **population** and (2) variation in the expression of that genetic information—that is, **trait variation**—that leads to differences in performance among individuals. The traits that positively affect survival are more likely to be **reproduced** and thus are more common in the population. [4 (p. 164)]

Natural selection is the result of four factors: **(1)** the potential for a species to increase in number, **(2)** the **genetic variation** of individuals in a species due to **mutation** and **sexual reproduction**, **(3)** competition for an environment's limited supply of the **resources** that individuals need in order to **survive** and **reproduce**, and **(4)** the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. **Natural selection** leads to **adaptation** —that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the **differential survival and reproduction** of organisms in a population that have an **advantageous heritable trait** leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Adaptation also means that the distribution of traits in a population can **change** when conditions change.

Changes in the **physical environment**, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the **extinction**—of some species. Species become extinct because they can no longer survive and reproduce in their **altered environment**. If members cannot adjust to change that is too fast or too drastic, the opportunity for the species' **evolution** is lost. [4 (pp. 165-166)]

Distribution of High School Standards; essential standards (HS) and course-specific plus (HS+)	U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	U2: The knowledge produced by science is used in engineering and technologies to create products.	U3: Applications of science often have both positive and negative ethical, social, economic, and political implications.
P1: All matter in the Universe is made of very small particles.	**Essential HS.P1U1.1** **Plus HS+C.P1U1.1** **Plus HS+C.P1U1.2** **Plus HS+C.P1U1.3** **Essential HS.P1U1.2** **Essential HS.P1U1.3** **Plus HS+C.P1U1.4** **Plus HS+C.P1U1.5** **Plus HS+C.P1U1.6** **Plus HS+C.P1U1.7**		**Essential HS.P1U3.4** **Plus HS+C.P1U3.8**
P2: Objects can affect other objects at a distance.	**Essential HS.P2U1.5** **Plus HS+Phy.P2U1.1**		
P3: Changing the movement of an object requires a net force to be acting on it.	**Essential HS.P3U1.6** **Plus HS+Phy.P3U1.2** **Plus HS+Phy.P3U1.3** **Plus HS+Phy.P3U1.4**	**Essential HS.P3U2.7** **Plus HS+Phy.P4U2.7** **Plus HS+Phy.P3U2.5**	
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.	**Essential HS.P4U1.8** **Plus HS+Phy.P4U1.6** **Plus HS+Phy.P4U1.8** **Essential HS.P4U1.10**		**Essential HS.P4U3.9**

Distribution of High School Standards; essential standards (HS) and course-specific plus (HS+)	U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	U2: The knowledge produced by science is used in engineering and technologies to create products.	U3: Applications of science often have both positive and negative ethical, social, economic, and political implications.
E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.	**Essential HS.E1U1.11** **Plus HS+E.E1U1.1** **Plus HS+E.E1U1.2** **Plus HS+E.E1U1.3** **Essential HS.E1U1.12** **Plus HS+E.E1U1.4** **Plus HS+E.E1U1.5** **Essential HS.E1U1.13** **Plus HS+E.E1U1.6** **Plus HS+E.E1U1.7** **Plus HS+E.E1U1.8**		**Essential HS.E1U3.14** **Plus HS+E.E1U3.9** **Plus HS+E.E1U3.10** **Plus HS+E.E1U3.11**
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.	**Essential HS.E2U1.15** **Plus HS+E.E2U1.12** **Essential HS.E2U1.16** **Plus HS+E.E2U1.13** **Plus HS+E.E2U1.14** **Essential HS.E2U1.17** **Plus HS+E.E2U1.15** **Plus HS+E.E2U1.16**	**Plus HS+E.E2U2.17**	

Distribution of High School Standards; essential standards (HS) and course-specific plus (HS+)	U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	U2: The knowledge produced by science is used in engineering and technologies to create products.	U3: Applications of science often have both positive and negative ethical, social, economic, and political implications.
L1: Organisms are organized on a cellular basis and have a finite life span.	**Essential HS.L1U1.20** **Plus HS+B.L1U1.4** **Plus HS+B.L1U1.5** **Plus HS+B.L1U1.6** **Plus HS+B.L1U1.7** **Essential HS.L1U1.22** **Plus HS+B.L1U1.9**		**Essential HS.L1U3.23**
L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.	**Plus HS+B.L2U1.1** **Essential HS.L2U1.19** **Plus HS+B.L2U1.3** **Essential HS.L2U1.21** **Plus HS+B.L2U1.8**		**Essential HS.L2U3.18**
L3: Genetic information is passed down from one generation of organisms to another.	**Essential HS.L3U1.24** **Essential HS.L3U1.25** **Plus HS+B.L3U1.10** **Plus HS+B.L3U1.11** **Plus HS+B.L3U1.12**		**Essential HS.L3U3.26**
L4: The unity and diversity of organisms, living and extinct, is the result of evolution.	**Plus HS+B.L4U1.2** **Essential HS.L4U1.27** **Essential HS.L4U1.28** **Plus HS+B.L4U1.13** **Plus HS+B.L4U1.14**		

Appendices

Appendix 1: Crosscutting Concepts

The seven crosscutting concepts bridge disciplinary boundaries and unite core ideas throughout the fields of science and engineering. Their purpose is to help students deepen their understanding of the core ideas in the standards and develop a coherent and scientifically based view of the world. Students should make explicit connections between their learning and the crosscutting concepts within each grade level.

These concepts also bridge the boundaries between science and other disciplines. As educators focus on crosscutting concepts, they should look for ways to integrate them into other disciplines. For example, patterns are highly prevalent in language. Indeed, phonics, an evidence-based literacy instructional strategy, is specifically designed to assist students in recognizing patterns in language. By actively incorporating these types of opportunities, educators assist students in building connections across content areas to deepen and extend learning.

The crosscutting concepts and their progressions from *Chapter 4 Crosscutting concepts pages 83 - 102 in A Framework for K-12 Science Education*[4] are summarized below.

Patterns*:* Observed patterns of forms and events guide organization and classification and prompt questions about relationships and the factors that influence them.
Patterns are often a first step in organizing and asking scientific and engineering questions. In science, classification is one example of recognizing patterns of similarity and diversity. In engineering, patterns of system failures may lead to design improvements. Assisting children with pattern recognition facilitates learning causing the brain to search for meaning in real-world phenomena.[1] Pattern recognition progresses from broad similarities and differences in young children to more detailed, scientific descriptors in upper elementary. Middle school students recognize patterns on both the micro- and macroscopic levels, and high school students understand that patterns vary in a system depending upon the scale at which the system is studied.
Cause and effect: Events have causes, sometimes simple, sometimes multifaceted. A major activity of both science and engineering is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
Like patterns, a child's ability to recognize cause and effect relationships progresses as they age. In the early grades, students build upon their understanding of patterns to investigate the causes of these patterns. They may wonder what caused one seed to grow faster than another one and design a test to gather evidence. By upper elementary, students should routinely be asking questions related to cause and effect. In middle school, students begin challenging others' explanations about causes through scientific argumentation. High school continues this trend while students expand their investigation into mechanisms that may

have multiple mediating factors such as changes in ecosystems over time or mechanisms that work in some systems but not in others.
Scale, proportion, and quantity: In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
There are two major scales from which we study science: directly observable and those processes which required tools or scientific measurement to be quantified and studied. To understand scale, students must understand both measurement and orders of magnitude. Understanding of scale, proportion, and quantity will progress as children get older. Young children engage in relative measures such as hotter/colder, bigger/smaller, or older/younger without referring to a specific unit of measure. As students age, it is important that they recognize the need for a common unit of measure to make a judgement of scale, proportion, and quantity. Elementary students start building this knowledge through length measurements and gradually progress to weight, time, temperature or other variables. Intersection with key mathematical concepts is vital to help students develop the ability to assign meaning to ratios and proportions when discussing scale, proportion, and quantity in science and engineering. By middle and high school, students apply this knowledge to algebraic thinking and are able to change variables, understand both linear and exponential growth, and engage in complex mathematical and statistical relationships.
Systems and system models: Because the world is too large and complex to comprehend all at once, students must define the system under study, specify its boundaries, and make explicit a model of that system provides tools for understanding and testing ideas that are applicable throughout science and engineering.
Models of systems can also be useful in conveying information about that system to others. Many engineering designs start with system models as a way to predict outcomes and test theories prior to final development ensuring that interactions between system parts and subsystems are understood. As students age, their ability to analyze and predict outcomes strengthens. In the early grades, students should be asked to express systems thinking through drawings, diagrams, or oral explanations noting relationships between parts. Additionally, even at a young age, students can be asked to develop plans for their actions or sets of instructions to help them develop the concept that others should be able to understand and use them. As student's age, they should incorporate more facets of the system including those facets which are not visible such as energy flow. By high school, students can identify the assumptions and approximations that went into making the system model and discuss how these assumptions and approximations limit the precision and reliability of predictions.

Energy and matter: Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
The concept of conservation of energy within a closed system is complex and prone to misunderstanding. As a result, students in early elementary are only very generally exposed to the concept of energy. In the early grades, focus on the recognition of conservation of matter within a system and the flow of matter between systems builds the basis for understanding more complex energy concepts in later grades. In middle school and high school, students develop a deeper understanding of this concept through chemical reactions and atomic structure. In high school, nuclear processes are introduced along with conservation laws related specifically to nuclear processes.
Structure and function: The way in which an object or living thing is shaped and its substructure determines many of its properties and functions.
Knowledge of structure and function is essential to successful design. As such, it is important that students begin an investigation of structure and function at an early age. In early grades, this study takes the form of how shape and stability are related for different structures: braces make a bridge stronger, a deeper bowl holds more water. In upper elementary and middle school, students begin an investigation of structures that are not visible to the naked eye: how the structure of water and salt molecules relate to solubility, the shape of the continents and plate tectonics. In high school students apply their knowledge of the relationship of structure to function when investigating the structure of the heart and the specific function it performs.
Stability and change: For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.
When systems are stable, small disturbances fade away, and the system returns to the stable condition. In maintaining a stable system, whether it is a natural system or a human design, feedback loops are an essential element. Young children experiment with stability and change as they build with blocks or chart growth. As they experiment with these concepts, the educator should assist them in building associated language and vocabulary as well as learning to question why some things change, and others stay the same. In middle school, understanding of stability and change extends beyond those phenomena which are easily visible to more subtle form of stability and change. By high school, students bring in their knowledge of historical events to explain stability and change over long periods of time, and they also recognize that multiple factors may feed into these concepts of stability and change.

Appendix 2: Science and Engineering Practices

The science and engineering practices describe how scientists investigate and build models and theories of the natural world or how engineers design and build systems. They reflect science and engineering as they are practiced and experienced. As students conduct investigations, they engage in multiple practices as they gather information to solve problems, answer their questions, reason about how the data provide evidence to support their understanding and then communicate their understanding of phenomena. Student investigations may be observational, experimental, use models or simulations, or use data from other sources. These eight practices identified in *Chapter 4 of A Framework for K-12 Science Education*[4] are critical components of scientific literacy. They are not instructional strategies.

Distinguishing Science & Engineering Practices

	Science	Engineering
Ask Questions and Define Problems	Science often begins with a question about a phenomenon, such as “Why is the sky blue?” or “What causes cancer?” and seeks to develop theories that can provide explanatory answers to such questions. Scientists formulate empirically answerable questions about phenomena; they establish what is already known and determine what questions have yet to be satisfactorily answered.	Engineering begins with a problem, need, or desire that suggests a problem that needs to be solved. A problem such as reducing the nation’s dependence on fossil fuels may produce multiple engineering problems like designing efficient transportation systems or improved solar cells. Engineers ask questions to define the problem, determine criteria for a successful solution, and identify constraints.
Develop and Use Models	Science often involves constructing and using a variety of models and simulations to help develop explanations about natural phenomena. Models make it possible to go beyond what can be observed. Models enable predictions to be made to test hypothetical explanations.	Engineering uses models and simulations to analyze existing systems to see where flaws might occur or to test viable solutions to a new problem. Engineers use models of various sorts to test proposed systems and to recognize the strengths and limitations of their designs.
Plan and Carry Out Investigations	Scientific investigations may be conducted in the field or the laboratory. Scientists plan and carry out systematic investigations that require the identification of what is to be recorded and, if applicable, what are to be treated as the dependent and independent variables. Observations and data collected are used to test existing theories and explanations or to revise and develop new ones.	Engineers use investigations to gather data essential for specifying design criteria or parameters and to test their designs. Engineers must identify relevant variables, decide how they will be measured, and collect data for analysis. Their investigations help them to identify how effective, efficient, and durable their designs may be under a range of conditions.

Analyze and Interpret Data	Scientific investigations produce data that must be analyzed to derive meaning. Because data usually do not speak for themselves, scientists use a range of tools, including tabulation, graphical interpretation, visualization, and statistical analysis, to identify significant features and patterns in the data, sources of error, and the calculated degree of certainty. Technology makes collecting large data sets easier providing many secondary sources for analysis.	Engineers analyze data collected during the tests of their designs and investigations; this allows them to compare different solutions and determine how well each one meets specific design criteria; that is, which design best solves the problem within the given constraints. Engineers require a range of tools to identify the major patterns and interpret the results.
Use Mathematics and Computational Thinking	In science, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks: constructing simulations, statistically analyzing data, and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable the behavior of physical systems to be predicted and tested. Statistical techniques are invaluable for assessing the significance of patterns or correlations.	In engineering**,** mathematical and computational representations of established relationships and principles are a fundamental part of design. For example, structural engineers create mathematically based analyses of designs to calculate whether they can stand up to the expected stresses of use and if they can be completed within acceptable budgets. Simulations of designs provide an effective test bed for the development.
Construct Explanations and Design Solutions	In science, theories are constructed to provide explanatory accounts of phenomena. A theory becomes accepted when it has been shown to be superior to other explanations in the breadth of phenomena it accounts for and in its explanatory coherence. Scientific explanations are explicit applications of theory to a specific situation or phenomenon, perhaps with a theory-based model for the system under study. The goal for students is to construct logically coherent explanations of phenomena that incorporate their current understanding of science, or a model that represents it, and are consistent with the available evidence.	Engineering design is a systematic process for solving engineering problems and is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, feasibility, cost, safety, aesthetics, and compliance with legal requirements. There is usually no single best solution but rather a range of solutions. The optimal solution often depends on the criteria used for making evaluations.

Engage in Argument from Evidence	In science, reasoning and argument are essential for identifying the strengths and weaknesses of a line of thinking and for finding the best explanation for a phenomenon. Scientists must defend their explanations, formulate evidence, based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomenon being investigated.	In engineering, reasoning and argument are essential for finding the best possible solution to a problem. Engineers collaborate with their peers throughout the design process, with a critical stage being the selection of the most promising solution among a field of competing ideas. Engineers use systematic methods to compare alternatives, formulate evidence, based on test data, make arguments from evidence to defend their conclusions, evaluate critically the ideas of others, and revise their designs to achieve the best solution to the problem at hand.
Obtain, Evaluate, and Communicate Information	Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. Scientists need to express their ideas, orally and in writing, using tables, diagrams, graphs, drawings, equations, or models and by engaging in discussions with peers. Scientists need to be able to derive meaning from texts (such as papers, the internet, symposia, and lectures) to evaluate the scientific validity of the information and to integrate that information with existing theories or explanations. Scientists routinely use technologies to extend the possibilities for collaboration and communication.	Engineers cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively. Engineers need to express their ideas, orally and in writing, using tables, graphs, drawings, or models and by engaging in discussions with peers. Engineers need to be able to derive meaning from colleagues' texts, evaluate the information, and apply it usefully. Engineers routinely use technologies to extend the possibilities for collaboration and communication.

[4]Adapted from Box 3-2, National Research Council. pages 50-53

Appendix 3: Core Ideas

The core ideas encompass the content that occurs at each grade and provides the background knowledge for students to develop sense-making around phenomena. The core ideas center around understanding the causes of phenomena in physical, earth and space, and life science; the principles, theories, and models that support that understanding; engineering and technological applications; and societal implications. The Arizona Science Standards integrate learning progressions from *A Framework for K-12 Science Education* [4] to build a coherent progression of learning for these core ideas from elementary school through high school. The following thirteen big ideas for knowing science and using science are adapted from *Working with Big Ideas of Science Education*[2] and represent student understanding of each core idea at the end of high school.

Core Ideas for Knowing Science	
P1: All matter in the Universe is made of very small particles.	Atoms are the building blocks of all normal matter, living and nonliving. The behavior and arrangement of the atoms explains the properties of different materials. In chemical reactions atoms are rearranged to form new substances. Each atom has a nucleus, containing neutrons and protons, surrounded by electrons. The opposite electric charges of protons and electrons attract each other, keeping atoms together and accounting for the formation of some compounds.
P2: Objects can affect other objects at a distance.	All objects have an effect on other objects without being in contact with them. In some cases, the effect travels out from the source to the receiver in the form of radiation such as visible light. In other cases, action at a distance is explained in terms of the existence of a field of influence between objects, such as a magnetic, electric, or gravitational field. Gravity is a universal force of attraction between all objects, however large or small, keeping the planets in orbit around the Sun and causing terrestrial objects to fall towards the center of the Earth.
P3: Changing the movement of an object requires a net force to be acting on it.	A force acting on an object is not seen directly but is detected by its effect on the object's motion or shape. If an object is not moving, the forces acting on it are equal in size and opposite in direction, balancing each other. Since gravity affects all objects on Earth, there is always another force opposing gravity when an object is at rest. Unbalanced forces cause change in movement in the direction of the net force. When opposing forces acting on an object are not in the same line they cause the object to turn or twist. This effect is used in some simple machines.
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.	The total amount of energy in the Universe is always the same but can be transferred from one energy store to another during an event. Many processes or events involve changes and require an energy source to make them happen. Energy can be transferred from one body or group of bodies to another in various ways. In these processes, some energy becomes less easy to use. Energy cannot be created or destroyed.

E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate.	Radiation from the Sun heats the Earth's surface and causes convection currents in the air and oceans creating climates. Below the surface, heat from the Earth's interior causes movement in the molten rock. This in turn leads to movement of the plates which form the Earth's crust, creating volcanoes and earthquakes. The solid surface is constantly changing through the formation and weathering of rock.
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.	Our Sun and eight planets and other smaller objects orbiting it comprise the solar system. Day and night and the seasons are explained by the orientation and rotation of the Earth as it moves round the Sun. The solar system is part of a galaxy of stars, gas, and dust. It is one of many billions in the Universe, enormous distances apart. Many stars appear to have planets.

L1: Organisms are organized on a cellular basis and have a finite life span.	All organisms are constituted of one or more cells. Multicellular organisms have cells that are differentiated according to their function. All the basic functions of life are the result of what happens inside the cells which make up an organism. Growth is the result of multiple cell divisions.
L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.	Food provides materials and energy for organisms to carry out the basic functions of life and to grow. Green plants and some bacteria are able to use energy from the Sun to generate complex food molecules. Animals obtain energy by breaking down complex food molecules and are ultimately dependent on producers as their source of energy. In any ecosystem, there is competition among species for the energy resources and materials they need to live and reproduce.
L3: Genetic information is passed down from one generation of organisms to another.	Genetic information in a cell is held in the chemical DNA. Genes determine the development and structure of organisms. In asexual reproduction all the genes in the offspring come from one parent. In sexual reproduction half of the genes come from each parent.
L4: The unity and diversity of organisms, living and extinct, is the result of evolution.	All life today is directly descended from a universal common ancestor. Over countless generations changes resulting from natural diversity within a species are believed to lead to the selection of those individuals best suited to survive under certain conditions. Species not able to respond sufficiently to changes in their environment become extinct.

Core Ideas for Using Science	
U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	**Science's purpose is to find the cause or causes of phenomena in the natural world.** Science is a search to explain and understand phenomena in the natural world. There is no single scientific method for doing this; the diversity of natural phenomena requires a diversity of methods and instruments to generate and test scientific explanations. [2 (p. 30)] **Scientific explanations, theories, and models are those that best fit the evidence available at a particular time.** A scientific theory or model representing relationships between variables of a natural phenomenon must fit the observations available at the time and lead to predictions that can be tested. Any theory or model is provisional and subject to revision in the light of new data even though it may have led to predictions in accord with data in the past. [2 (31)]
U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.	The use of scientific ideas in engineering and technologies has made considerable changes in many aspects of human activity. Advances in technologies enable further scientific activity; in turn, this increases understanding of the natural world. In some areas of human activity technology is ahead of scientific ideas, but in others scientific ideas precede technology. [2 (p. 32)]
U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.	The use of scientific knowledge in technologies makes many innovations possible. Whether particular applications of science are desirable is a matter that cannot be addressed using scientific knowledge alone. Ethical and moral judgments may be needed, based on such considerations as personal beliefs, justice or equity, human safety, and impacts on people and the environment. [2 (p. 33)]

Appendix 4: Equity & Diversity in Science

All students can and should learn complex science. However, achieving equity in science education is an ongoing challenge. Students from underrepresented communities often face "opportunity gaps" in their educational experience. Inclusive approaches to science instruction can reposition youth as meaningful participants in science learning and recognize their science-related assets and those of their communities[4].

The science and engineering practices have the potential to be inclusive of students who have traditionally been marginalized in the science classroom and may not see science as being relevant to their lives or future. These practices support sense-making and language use as students engage in a classroom culture of discourse[6]. The science and engineering practices can support bridges between literacy and numeracy needs, which is particularly helpful for non-dominant groups when addressing multiple "opportunity gaps." By solving problems through engineering in local contexts (gardening, improving air quality, cleaning water pollution in the community), students gain knowledge of science content, view science as relevant to their lives and future, and engage in science in socially relevant and transformative ways[7]. Science teachers need to acquire effective strategies to include all students regardless of age, racial, ethnic, cultural, linguistic, socioeconomic, and gender backgrounds[3].

Effective teaching strategies[3] for attending to equity and diversity for

- **Economically disadvantaged students** include (1) connecting science education to students' sense of "place" as physical, historical, and sociocultural dimensions in their community; (2) applying students' "funds of knowledge" and cultural practices; and (3) using problem-based and project-based science learning centered on authentic questions and activities that matter to students.
- **Underrepresented racial and ethnic groups** include (1) culturally relevant pedagogy, (2) community involvement and social activism, (3) multiple representations and multimodal experiences, and (4) school support systems including role models and mentors of similar racial or ethnic backgrounds.
- **Indigenous students** include (1) learning and knowing that is land- and place-based, (2) centers (not erases or undermines) their ways of knowing, and (3) builds connections between Indigenous and western Science Technology Engineering and Mathematics (STEM), and (4) home culture connections[8].
- **Students with disabilities** include (1) multiple means of representation, (2) multiple means of action and expression, (3) multiple means of engagement, (4) concrete experiences with realia, and (5) scaffolds in problem-based and project-based learning.
- **English language learners** include (1) literacy strategies for all students, (2) language support strategies with English language learners, (3) discourse strategies with English language learners, (4) home language support, (5) home culture connections, (6) concrete experiences with realia, and (7) scaffolds in problem-based and project-based learning.
- **Alternative education setting for dropout prevention** include (1) structured after-school opportunities, (2) family outreach, (3) life skills training, (4) safe learning environment, and (5) individualized academic support.
- **Girls' achievement, confidence, and affinity with science** include (1) instructional strategies, (2) curricular decisions, and (3) classroom and school structure.
- **Gifted and talented students** include (1) different levels of challenge (including differentiation of content), (2) opportunities for self-direction, and (3) strategic grouping.

Appendix 5: Interdisciplinary Connections

The crosscutting concepts along with the science and engineering practices provide opportunities for developing strong interdisciplinary connections across all content areas. Understanding core ideas in science can provide a context for helping students master key competencies from other content areas. It can also promote essential career readiness skills, including communication, creativity, collaboration, and critical thinking. This affords all students equitable access to learning and ensures all students are prepared for college, career, and citizenship.

English Language Arts
The science and engineering practices incorporate reasoning skills used in language arts to help students improve mastery and understanding in reading, writing, speaking, and listening. The intersections between science and ELA teach students to analyze data, model concepts, and strategically use tools through productive talk and shared activity. Evidence-based reasoning is the foundation of good scientific practice. Reading, writing, speaking, and listening in science requires an appreciation of the norms and conventions of the discipline of science, including understanding the nature of evidence used, an attention to precision and detail, and the capacity to make and assess intricate arguments, verbally and orally present findings, synthesize complex information, and follow detailed procedures and accounts of events and concepts. To support these disciplinary literacy skills, teachers must foster a classroom culture where students think and reason together, connecting around the core ideas, science and engineering practices, and the crosscutting concepts.

Mathematics
Science is a quantitative discipline, so it is important for educators to ensure that students' science learning coheres well with their understanding of mathematics.[5] Mathematics is fundamental to aspects of modeling and evidence-based conclusions. It is essential for expressing relationships in quantitative data. The Standards for Mathematical Practice (MP) naturally link to the science and engineering practices and multiple crosscutting concepts within the Arizona Science Standards. By incorporating the Arizona Mathematics Standards and practices with critical thinking in science instruction, educators provide students with opportunities to develop literacy in mathematics instruction. The goal of using mathematical skills and practices in science is to foster a deeper conceptual understanding of science.

Health
Natural connections between Health and science exist throughout the Standards. The goals of Health being to maintain and improve students' health, prevent disease, and avoid or reduce health-related risk behaviors which can fit within the context of science standards.

Computer Science
Natural connections between science and computer science exist throughout the Standards, especially in the middle level and in high school. As students develop or refine complex models and simulations of natural and designed systems, they can use computer science to develop, test, and use mathematical or computational models to generate data. Students can apply computational thinking and coding to develop apps or streamline processes for collecting, analyzing, or interpreting data.

Technology
Technology is essential in teaching and learning science; it influences the science that is taught and enhances students' learning. Technologies in science run the range from tools for performing experiments or collecting data (thermometers, temperature probes, microscopes, centrifuges) to digital technologies for completing analysis or displaying data (calculators, computers). All of them are essential tools for teaching, learning, and doing science. Computers and other digital tools allow students to collect, record, organize, analyze, and communicate data as they engage in science learning. They can support student investigations in every area of science. When technology tools are available, students can focus on decision making, reflection, reasoning, and problem solving. Connections to engineering, technology, and applications of science are included at all grade levels and in all domains. These connections highlight the interdependence of science, engineering, and technology that drives the research, innovation, and development cycle where discoveries in science lead to new technologies developed using the engineering design process. Additionally, these connections call attention to the effects of scientific and technological advances on society and the environment.

Social Studies
Natural connections between the core ideas for using science and social studies exist throughout the Standards. Students need a foundation in social studies to understand how ethical, social, economic, and political issues of the past and present impact the development and communication of scientific theories, engineering and technological developments, and other applications of science and engineering. Students can use historical, geographic, and economic perspectives to understand that all cultures have ways of understanding phenomena in the natural world and have contributed and continue to contribute to the fields of science and engineering. Sustainability issues and citizen science provide contemporary contexts for integrating social studies with science. Citizen science is the public involvement in inquiry and discovery of new scientific knowledge. This engagement helps students build science knowledge and skills while improving social behavior, increasing student engagement, and strengthening community partnerships. Citizen science projects enlist K-12 students to collect or analyze data for real-world research studies, which helps students develop a deep knowledge of geography, economics, and civic issues of specific regions.

Appendix 6: Connections to English Language Arts and Math

Kindergarten - 2nd Grade

	Kindergarten	1st Grade	2nd Grade
Arizona English Language Arts	Use age-appropriate scientific texts and biographies to develop instruction that integrates the Reading Standards for Informational Text, the Reading Standards for Foundational Skills, and the Writing Standards		
Arizona Mathematics Standards	**Standards for Mathematical Practices** -Make sense of problems and persevere in solving them -Use appropriate tools strategically -Look for and make use of structure -Look for and express regularity in repeated reasoning **Counting and Cardinality** -Develop competence with counting and cardinality -Develop understanding of addition and subtraction within 10 **Measurement and Data** -Describe and compare measurable attributes -Classify objects and count the number of objects in each category	**Standards for Mathematical Practice** -Make sense of problems and persevere in solving them -Use appropriate tools strategically -Construct viable arguments and critique the reasoning of others -Attend to precision -Look for and make use of structure -Look for and express regularity in repeated reasoning **Measurement and Data** -Measure lengths indirectly and by iterating length units -Represent and interpret data **Geometry** -Reason with shapes and their attribute	**Standards for Mathematical Practice** -Make sense of problems and persevere in solving them -Use appropriate tools strategically -Construct viable arguments and critique the reasoning of others. -Attend to precision -Look for and make use of structure -Look for and express regularity in repeated reasoning **Operations and Algebraic Thinking** -Represent and solve problems involving addition and subtraction **Number and Operations in Base Ten** -Use place value understanding and properties of operations to add and subtract **Measurement and Data** -Represent and interpret data -Measure the length of an object using an appropriate tool including metrics.

3rd Grade - 5th Grade

	3rd Grade	4th Grade	5th Grade
Arizona English Language Arts	Use age-appropriate scientific texts and biographies to develop instruction that integrates the Reading Standards for Informational Text, the Reading Standards for Foundational Skills, and the Writing Standards		
Arizona Mathematics Standards	**Standards for Mathematical Practices** -Make sense of problems and persevere in solving them -Reason abstractly and quantitatively -Use appropriate tools strategically -Construct viable arguments and critique the reasoning of others -Use appropriate tools strategically -Attend to precision -Look for and make use of structure **Operations and Algebraic Thinking** -Represent and solve problems involving addition and subtraction **Number and Operations in Base Ten** -Use place value understanding and properties of operations to perform multi-digit arithmetic **Number and Operations - Fractions** -Understand fractions as numbers **Measurement and Data** -Measure and estimate liquid volumes and masses of objects -Solve problems involving measurement -Represent and interpret data	**Standards for Mathematical Practice** -Make sense of problems and persevere in solving them -Use appropriate tools strategically -Construct viable arguments and critique the reasoning of others -Attend to precision -Look for and make use of structure -Look for and express regularity in repeated reasoning **Operations and Algebraic Thinking** -Use place value understanding and properties of operations to perform multi-digit arithmetic **Number and Operations in Base Ten** **Number and Operations - Fractions** -Understand decimal notation for fractions and compare decimal fractions **Measurement and Data** -Solve problems involving measurement and conversion of measurements from a larger unit to a smaller unit -Represent and interpret data	**Standards for Mathematical Practice** -Make sense of problems and persevere in solving them reason abstractly and quantitatively -Construct viable arguments and critique the reasoning of other -Model with mathematics -Use appropriate tools strategically -Attend to precision -Look for and make use of structure -Look for and express regularity in repeated reasoning **Operations and Algebraic Thinking** -Write and interpret numerical expressions. -Analyze patterns and relationships **Measurement and Data** -Convert like measurement units within a given measurement system -Represent and interpret data -Solve problems involving measurement and conversion of measurements from a larger unit to a smaller unit -Solve problems involving measurement -Geometric measurement; understand concepts of volume and relate volume to multiplication and division.

6th Grade - 8th Grade

	6th Grade	7th Grade	8th Grade
Arizona English Language Arts	Use age-appropriate scientific texts and biographies to develop instruction surrounding the Reading Standards for Informational Use age-appropriate scientific texts and biographies to develop instruction that integrates the Reading Standards for Informational Text, and the Writing Standards		
Arizona Mathematics Standards	**Standards for Mathematical Practices** -Make sense of problems and persevere in solving them -Reason abstractly and quantitatively -Use appropriate tools strategically -Construct viable arguments and critique the reasoning of others -Use appropriate tools strategically -Attend to precision -Look for and make use of structure -Model with mathematics -Look for and express regularity in repeated reasoning **Ratios and Proportional Relationships** -Understand ratio concepts and use ratio reasoning to solve problems **Expressions and Equations** -Represent and analyze quantitative relationships between dependent and independent variable **Geometry** -Solve mathematical problems and problems in real-world context involving area, surface area and volume	**Standards for Mathematical Practice** -Make sense of problems and persevere in solving them -Reason abstractly and quantitatively -Use appropriate tools strategically -Construct viable arguments and critique the reasoning of others -Attend to precision -Look for and make use of structure -Look for and express regularity in repeated reasoning -Model with mathematics **Statistics and Probability** -Use random sampling to draw inferences about a population -Draw informal comparative inferences about two populations -Investigate chance processes and develop, use, and evaluate probability models	**Standards for Mathematical Practice** -Make sense of problems and persevere in solving them -Reason abstractly and quantitatively -Use appropriate tools strategically -Construct viable arguments and critique the reasoning of others. -Attend to precision -Look for and make use of structure -Look for and express regularity in repeated reasoning -Model with mathematics **Expressions and Equations** -Understand the connections between proportional relationships, lines, and linear equations **Functions** -Use functions to model relationships between quantities **Statistics and Probability** -Investigate patterns of association in bivariate data -Investigate chance processes and develop, use, and evaluate probability models

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K-12 Crosscutting Concepts* Progression Matrix of Elements

For use with *Arizona Science Standards*

1. Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	▪ Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products. ▪ Patterns of change can be used to make predictions. ▪ Patterns can be used as evidence to support an explanation.	▪ 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, charts, and images can be used to identify patterns in data.	▪ Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ▪ Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. ▪ Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system. ▪ Mathematical representations are needed to identify some patterns. ▪ Empirical evidence is needed to identify patterns.

2. Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Events have causes that generate observable patterns. ▪ Simple tests can be designed to gather evidence to support or refute student ideas about causes.	▪ Cause and effect relationships are routinely identified, tested, and used to explain change. ▪ Events that occur together with regularity might or might not be a cause and effect relationship.	▪ 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.	▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. ▪ Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. ▪ Systems can be designed to cause a desired effect. ▪ Changes in systems may have various causes that may not have equal effects.

* Adapted by Achieve from: National Research Council (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academy Press. Chapter 4: Crosscutting Concepts.

K-12 Crosscutting Concepts* Progression Matrix of Elements

For use with *Arizona Science Standards*

3. Scale, Proportion, and Quantity – In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

K-2 Crosscutting Statements	3-5 Crosscutting Statements	6-8 Crosscutting Statements	9-12 Crosscutting Statements
▪ Relative scales allow objects and events to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). ▪ Standard units are used to measure length.	▪ Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods. ▪ Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.	▪ 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. ▪ 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. ▪ Phenomena that can be observed at one scale may not be observable at another scale.	▪ The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ▪ Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. ▪ Patterns observable at one scale may not be observable or exist at other scales. ▪ Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. ▪ Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

4. Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

K-2 Crosscutting Statements	3-5 Crosscutting Statements	6-8 Crosscutting Statements	9-12 Crosscutting Statements
▪ Objects and organisms can be described in terms of their parts. ▪ Systems in the natural and designed world have parts that work together.	▪ A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. ▪ A system can be described in terms of its components and their interactions.	▪ 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.	▪ Systems can be designed to do specific tasks. ▪ When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. ▪ Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. ▪ Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

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K-12 Crosscutting Concepts* Progression Matrix of Elements

For use with *Arizona Science Standards*

5. Energy and Matter: Flows, Cycles, and Conservation – Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Objects may break into smaller pieces, be put together into larger pieces, or change shapes.	▪ Matter is made of particles. ▪ Matter flows and cycles can be tracked in terms of the weight of the substances before and after a process occurs. The total weight of the substances does not change. This is what is meant by conservation of matter. Matter is transported into, out of, and within systems. ▪ Energy can be transferred in various ways and between objects.	▪ 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.	▪ The total amount of energy and matter in closed systems is conserved. ▪ Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. ▪ Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. ▪ Energy drives the cycling of matter within and between systems. ▪ In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

6. Structure and Function – The way an object is shaped or structured determines many of its properties and functions.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ The shape and stability of structures of natural and designed objects are related to their function(s).	▪ Different materials have different substructures, which can sometimes be observed. ▪ Substructures have shapes and parts that serve functions.	▪ 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.	▪ Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. ▪ The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

7. Stability and Change – For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.			
K-2 Crosscutting Statements	**3-5 Crosscutting Statements**	**6-8 Crosscutting Statements**	**9-12 Crosscutting Statements**
▪ Some things stay the same while other things change. ▪ Things may change slowly or rapidly.	▪ Change is measured in terms of differences over time and may occur at different rates. ▪ Some systems appear stable, but over long periods of time will eventually 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.	▪ Much of science deals with constructing explanations of how things change and how they remain stable. ▪ Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. ▪ Feedback (negative or positive) can stabilize or destabilize a system. ▪ Systems can be designed for greater or lesser stability.

* Adapted by Achieve from: National Research Council (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academy Press. Chapter 4: Crosscutting Concepts.

K-12 Science and Engineering Practices* Progression Matrix of Elements

For use with *Arizona Science Standards*

Science and Engineering Practices	K–2 Condensed Practices	3–5 Condensed Practices	6–8 Condensed Practices	9–12 Condensed Practices
Asking Questions and Defining Problems A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.	Asking questions and defining problems in grades K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested. ▪ Ask questions based on observations of the natural and/or designed world. ▪ Define a simple problem that can be solved through the development of a new or improved object or tool.	Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships. ▪ Identify scientific (testable) and non-scientific (non-testable) questions. ▪ Ask questions based on careful observations of phenomena and information. ▪ Ask questions to clarify ideas or request evidence. ▪ Ask questions that relate one variable to another variable. ▪ Ask questions to clarify the constraints of solutions to a problem. ▪ Use prior knowledge to describe problems that can be solved. ▪ Define a simple design problem that can be solved through the development of an object, tool or process and includes several criteria for success and constraints on materials, time, or cost. ▪ Formulate questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.	Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to formulating and refining empirically testable models that support explanations of phenomena or solutions to problems. ▪ Ask questions that arise from careful observation of phenomena, models, or unexpected results. ▪ Ask questions to clarify or identify evidence and the premise(s) of an argument. ▪ Ask questions to determine relationships between independent and dependent variables. ▪ Ask questions that challenge the interpretation of a data set. ▪ Ask questions to clarify and refine a model, an explanation, or an engineering problem. ▪ Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible 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.	Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design solutions using models and simulations. ▪ Ask questions that arise from careful observation of phenomena, models, theory, or unexpected results. ▪ Ask questions that require relevant empirical evidence to answer. ▪ Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. ▪ Ask and evaluate questions that challenge the premise of an argument, the interpretation of a data set, or the suitability of a design. ▪ Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations

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K-12 Science and Engineering Practices* Progression Matrix of Elements

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Developing and Using Models A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.	Modeling in K–2 builds on prior experiences and progresses to include identifying, using, and developing models that represent concrete events or design solutions. ▪ Distinguish between a model and the actual object, process, and/or events the model represents. ▪ Compare models to identify common features and differences. ▪ Develop and/or use models (i.e., diagrams, drawings, physical replicas, dioramas, dramatizations, or storyboards) that represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed worlds. ▪ Develop a simple model that represents a proposed object or tool.	Modeling in 3–5 builds on K–2 models and progresses to building and revising simple models and using models to represent events and design solutions. ▪ Develop and revise models collaboratively to measure and explain frequent and regular events. ▪ Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. ▪ Use simple models to describe or support explanations for phenomena and test cause and effect relationships or interactions concerning the functioning of a natural or designed system. ▪ Identify limitations of models. ▪ Develop a diagram or simple physical prototype to convey a proposed object, tool or process. ▪ Use a simple model to test cause and effect relationships concerning the functioning of a proposed object, tool or process.	Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems. ▪ Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. ▪ Develop models to describe unobservable mechanisms. ▪ Modify models—based on their limitations—to increase detail or clarity, or to explore what will happen if a component is changed. ▪ Use and develop models of simple systems with uncertain and less predictable factors. ▪ Develop a model that allows for manipulation and testing of a proposed object, tool, process or system. ▪ Evaluate limitations of a model for a proposed object or tool.	Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world. ▪ Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. ▪ Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system. ▪ Use models (including mathematical and computational) to generate data to support explanations and predict phenomena, analyze systems, and solve problems. ▪ Design a test of a model to ascertain its reliability. ▪ Develop a complex model that allows for manipulation and testing of a proposed process or system. ▪ Evaluate merits and limitations of two different models of the same proposed tool, process, or system in order to select or revise a model that best fits the evidence or design criteria.

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Planning and Carrying Out Investigations Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.	Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. ▪ With guidance, design and conduct investigations in collaboration with peers. ▪ Design and conduct investigations collaboratively. ▪ Evaluate different ways of observing and/or measuring an attribute of interest. ▪ Make direct or indirect observations and/or measurements to collect data, which can be used to make comparisons. ▪ Identify questions and make predictions based on prior experiences. ▪ Make direct or indirect observations and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal.	Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. ▪ Design and conduct investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. ▪ Evaluate appropriate methods and tools for collecting data. ▪ Make observations and/or measurements, collect appropriate data, and identify patterns that provide evidence for an explanation of a phenomenon or test a design solution. ▪ Make measurements of two different models of the same proposed object, tool or process to determine which better meets criteria for success.	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. ▪ Conduct an investigation and evaluate and revise the experimental design to ensure that the data generated can meet the goals of the experiment. ▪ Design an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how much data are needed to support their claim. ▪ Evaluate the accuracy of various methods for collecting data. ▪ Collect data and generate evidence to answer scientific questions or test design solutions under a range of conditions. ▪ Collect data about the performance of a proposed object, tool, process or system under a range of conditions.	Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that build, test, and revise conceptual, mathematical, physical, and empirical models. ▪ Design an investigation individually and collaboratively and test designs as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. ▪ Design and conduct an investigation individually and collaboratively, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. ▪ Select appropriate tools to collect, record, analyze, and evaluate data. ▪ Design and conduct investigations and test design solutions in a safe and ethical manner including considerations of environmental, social, and personal impacts. ▪ Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. ▪ Use investigations to gather evidence to support explanations or concepts.

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Analyzing and Interpreting Data Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.	Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations. ▪ Use and share pictures, drawings, and/or writings of observations. ▪ Use observations to describe patterns and/or relationships in the natural and designed worlds in order to answer scientific questions and solve problems. ▪ Make measurements of length to quantify data. ▪ Analyze data from tests of an object or tool to determine if a proposed object or tool functions as intended.	Analyzing data in 3–5 builds on K–2 and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. ▪ Display data in tables and graphs, using digital tools when feasible, to reveal patterns that indicate relationships. ▪ Use data to evaluate claims about cause and effect. ▪ Compare data collected by different groups in order to discuss similarities and differences in their findings. ▪ Use data to evaluate and refine design solutions. ▪ Interpret data to make sense of and explain phenomena, using logical reasoning, mathematics, and/or computation. ▪ Analyze data to refine a problem statement or the design of a proposed object, tool or process.	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. ▪ Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. ▪ Construct, analyze, and interpret graphical displays of data to identify linear and nonlinear relationships. ▪ Consider limitations of data analysis (e.g., measurement error), and seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). ▪ Analyze and interpret data in order to determine similarities and differences in findings. ▪ Distinguish between causal and correlational relationships. ▪ Use graphical displays (e.g., maps) of large data sets to identify temporal and spatial relationships. ▪ Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. ▪ Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims or determine an optimal design solution. ▪ Consider limitations (e.g., measurement error, sample selection) when analyzing and interpreting data. ▪ Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. ▪ Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. ▪ Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. ▪ Evaluate the impact of new data on a working explanation of a proposed process or system.

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Using Mathematics and Computational Thinking In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.	Mathematical and computational thinking at the K–2 level builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world ▪ Decide when to use qualitative vs. quantitative data. ▪ Use counting and numbers to identify and describe patterns in the natural and designed worlds. ▪ Describe, measure, and compare quantitative attributes of different objects and display the data using simple graphs. ▪ Use quantitative data to compare two alternative solutions to a problem.	Mathematical and computational thinking at the 3–5 level builds on K–2 and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to compare alternative design solutions. ▪ Use mathematical thinking and/or computational outcomes to compare alternative solutions to an engineering problem. ▪ Organize simple data sets to reveal patterns that suggest relationships. ▪ Describe, measure, estimate, and graph quantities such as area, volume, weight, and time to address scientific and engineering questions and problems. ▪ Decide if qualitative or quantitative data is best to determine whether a proposed object or tool meets criteria for success.	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. ▪ Create algorithms (a series of ordered steps) to solve a problem. ▪ Apply concepts of ratio, rate, percent, basic operations, and simple algebra to scientific and engineering questions and problems. ▪ Use mathematical arguments to describe and support scientific conclusions and design solutions. ▪ Use digital tools, mathematical concepts, and arguments to test and compare proposed solutions to an engineering design problem.	Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. ▪ Use mathematical or algorithmic representations of phenomena or design solutions to describe and support claims and explanations, and create computational models or simulations. ▪ Apply techniques of algebra and functions to represent and solve scientific and engineering problems. ▪ Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. ▪ Create a simple computational model or simulation of a designed device, process, or system.

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Constructing Explanations and Designing Solutions *The end-products of science are explanations and the end-products of engineering are solutions.* The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.	Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence or ideas in constructing explanations and designing solutions. ▪ Use information from direct or indirect observations to construct explanations. ▪ Use tools and materials provided to design a device or solution to a specific problem. ▪ Distinguish between opinions and evidence in one's own explanations. ▪ Generate and compare multiple solutions to a problem.	Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions. ▪ Construct explanations of observed quantitative relationships (e.g., the distribution of plants in the back yard). ▪ Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. ▪ Identify the evidence that supports particular points in an explanation. ▪ Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation. ▪ Apply scientific knowledge to solve design problems. ▪ Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the problem.	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. ▪ Construct explanations for either qualitative or quantitative relationships between variables. ▪ Apply scientific reasoning to show why the data are adequate for the explanation or conclusion. ▪ Base explanations on evidence obtained from sources (including their own experiments) and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. ▪ Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints. ▪ Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events. ▪ Construct explanations from models or representations. ▪ Apply scientific knowledge to design, construct, and test a design of an object, tool, process or system. ▪ Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.	Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. ▪ Make quantitative and qualitative claims regarding the relationship between dependent and independent variables. ▪ Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. ▪ Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. ▪ Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. ▪ Apply scientific knowledge and evidence to explain phenomena and solve design problems, taking into account possible unanticipated effects. ▪ Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

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Engaging in Argument from Evidence *Argumentation is the process by which explanations and solutions are reached.* In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to identify strengths and weaknesses of claims.	Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world. ▪ Identify arguments that are supported by evidence. ▪ Listen actively to others' explanations and arguments and ask questions for clarification. ▪ Make a claim about the effectiveness of an object, tool, or solution that is based on relevant evidence.	Engaging in argument from evidence in 3–5 builds from K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world. ▪ Construct and/or support scientific arguments with evidence, data, and/or a model. ▪ Compare and refine arguments based on the strengths and weaknesses of the evidence presented. ▪ Respectfully provide and receive critiques on scientific arguments with peers by citing relevant evidence and posing specific questions. ▪ Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	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. ▪ Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem. ▪ Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. ▪ Respectfully provide and receive critiques on scientific arguments by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. ▪ Compare two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. ▪ Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system, based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.	Engaging in argument from evidence in 9–12 builds from K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world. Arguments may also come from current scientific or historical episodes in science. ▪ Critique and evaluate competing arguments, models, and/or design solutions in light of new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. ▪ Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. ▪ Construct a counter-argument that is based on data and evidence that challenges another proposed argument. ▪ Make and defend a claim about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. ▪ Evaluate a claim for a design solution to a real-world problem based on scientific knowledge, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

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Obtaining, Evaluating, and Communicating Information Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to acquire information that is used to evaluate the merit and validity of claims, methods, and designs.	Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information. ▪ Read and comprehend grade-appropriate texts and media to acquire scientific and/or technical information. ▪ Critique and/or communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers. ▪ Record observations, thoughts, and ideas. ▪ Explain how specific images (e.g., a diagram showing how a machine works) contribute to and clarify a text. ▪ Obtain information by using various text features (e.g., headings, tables of contents, glossaries, electronic menus, icons).	Obtaining, evaluating, and communicating information in 3–5 builds on K–2 and progresses to evaluating the merit and accuracy of ideas and methods. ▪ Compare and/or combine across complex texts and/or other reliable media to acquire appropriate scientific and/or technical information. ▪ Determine the main idea of a scientific text and explain how it is supported by key details; summarize the text. ▪ Combine information in written text with that contained in corresponding tables, diagrams, and/or charts. ▪ Use multiple sources to generate and communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. ▪ Use models to share findings or solutions in oral and/or written presentations, and/or extended discussions. ▪ Obtain and combine information from books and/or other reliable media about potential solutions to a specific design problem.	Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods. ▪ Communicate scientific information and/or technical information (e.g. about a proposed object, tool, process, system) in different formats (e.g., verbally, graphically, textually, and mathematically). ▪ Gather, read, and communicate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used. ▪ Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions that appear in scientific and technical texts in light of competing information or accounts; provide an accurate summary of the text distinct from prior knowledge or opinions. ▪ Critically evaluate whether or not technical information on a device, tool or process is relevant to its suitability to solve a specific design problem.	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. ▪ Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. ▪ Synthesize, communicate, and evaluate the validity and reliability of claims, methods, and designs that appear in scientific and technical texts or media reports, verifying the data when possible. ▪ Produce scientific and/or technical writing and/or oral presentations that communicate scientific ideas and/or the process of development and the design and performance of a proposed process or system. ▪ Compare, integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) in order to address a scientific question or solve a problem.

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