



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.

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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)

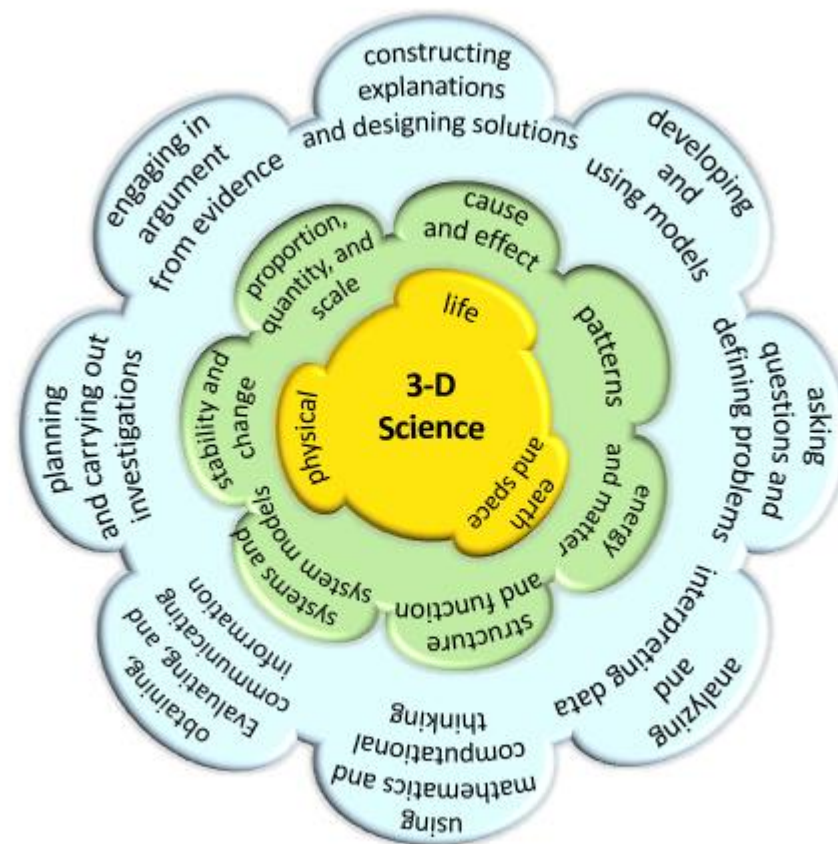


Figure 1: Three Dimensions of Science Instruction

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 practices⁴ 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

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Crosscutting Concepts

Crosscutting concepts⁴ 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.

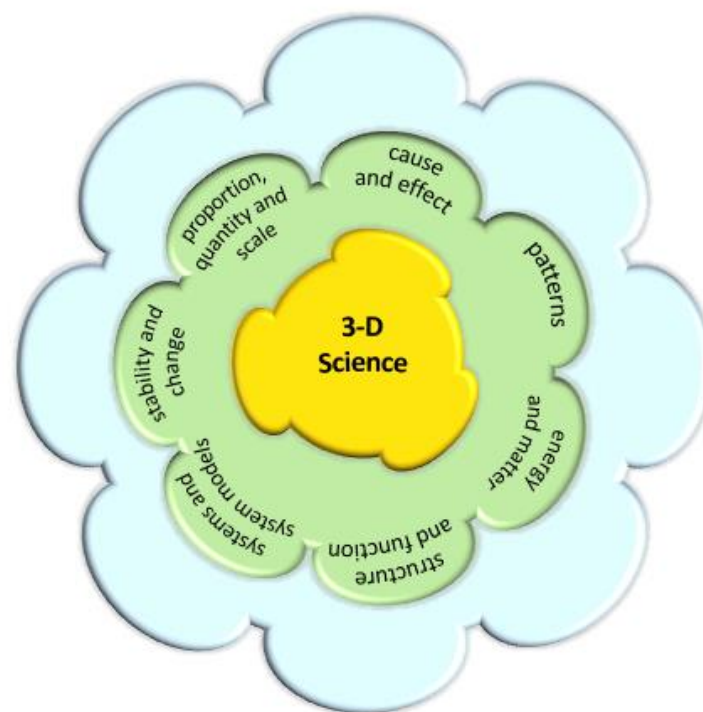


Figure 3: Crosscutting Concepts

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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.

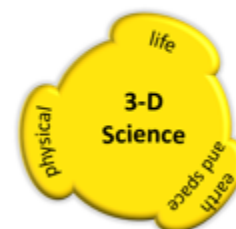


Figure 3: Core Ideas

Core Ideas for Knowing Science	Core Ideas for Using Science
<p>Physical Science</p> <p>P1: All matter in the Universe is made of very small particles.</p> <p>P2: Objects can affect other objects at a distance.</p> <p>P3: Changing the movement of an object requires a net force to be acting on it.</p> <p>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.</p> <p>Earth and Space Science</p> <p>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.</p> <p>E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.</p> <p>Life Science</p> <p>L1: Organisms are organized on a cellular basis and have a finite life span.</p> <p>L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.</p> <p>L3: Genetic information is passed down from one generation of organisms to another.</p> <p>L4: The unity and diversity of organisms, living and extinct, is the result of evolution.</p> <p>*Adapted from <i>Working with Big Ideas in Science Education</i>²</p>	<p>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.</p> <p>U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.</p> <p>U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.</p>

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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

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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 investigation⁵:

- 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

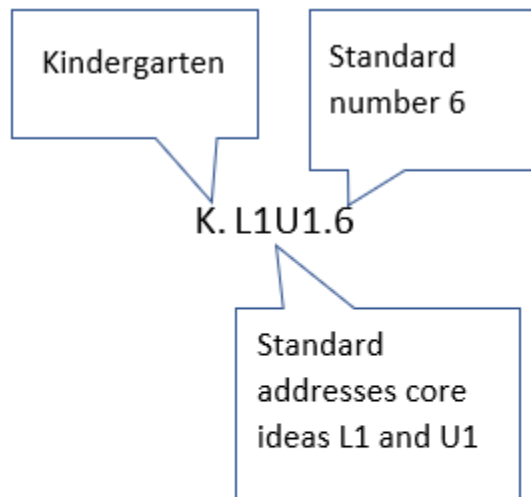
What You Can Do

- 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.

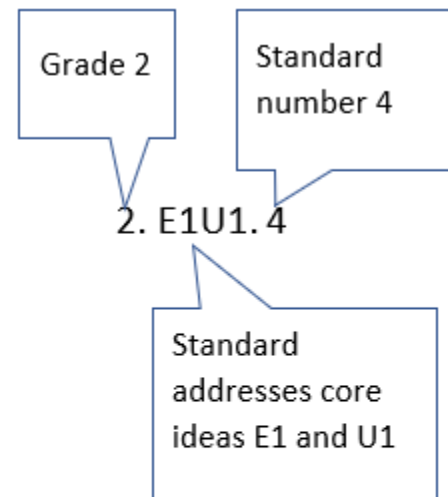
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Coding of the K-8 Science Standards

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.

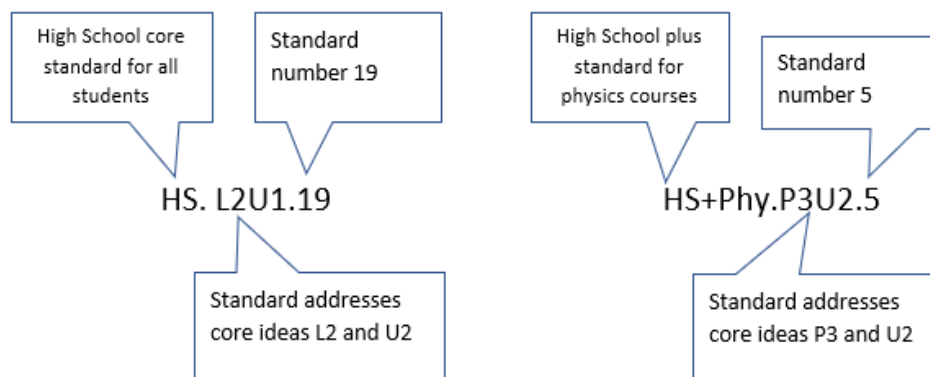
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Coding of the High School Science Standards

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.

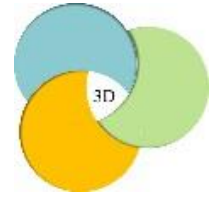
- All high school essential standards (HS) should be learned by every high school student regardless of the 3-credit course sequence they take. The full set of essential high school (HS) standards is designed to be taught over a 3-year period.
- The high school plus (HS+) standards are designed to enhance 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
<p>1.1.2U2.7</p> <p>Develop and use models about how living things use resources to grow and survive; design and evaluate habitats for organisms using earth materials.</p>	<p>Crosscutting Concepts & Background Information for Educators</p> <p>Crosscutting Concepts: Patterns, Cause and Effect, Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p>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(p. 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)</p>
<p>1.1.2U1.8</p> <p>Construct an explanation describing how organisms obtain resources from the environment including materials that are used again by other organisms.</p>	

Guide to Explain Standards

Standards	<p>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.</p>	<p>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.</p> <p>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.</p>	Support Material
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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 in the “Background Information”. This process of refining the support to the standards background information was prompted by the state board of education.

Date	Changes	Rationale
4/5/19 10/19/19	Grammar and formatting.	Consistency throughout document.
7/26/19	Introduction section 4 th 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 <i>A Framework for K-12 Science Education</i> and <i>Working with Big Ideas of Science Education</i> 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.

Date	Background Information	Changes	Rationale
9/25/19	Physical 6.1-3 Standard <i>Teacher Background</i> change	Added: Info from pg. 108 Framework	No information in original regarding temperature and pressure to give deeper background on standard regarding substances.
9/25/19	Life 7.10-12 Standard <i>Teacher Background</i> change	Added/Moved: Info from 6 th grade life standards from the background information (6.11-14), to Life 7 th grade standards 10-12.	The information connects better to 7 th grade life than it did to 6 th grade life. Identified by ASTA 5 Tools team while making unpacking cards.
9/25/19	7.E1U1.5 Standard <i>Teacher Background</i> change	Added/Moved: Info from 7.E1U1.7 earth standard from the background to 7.E1U1.5 standard	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.

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9/25/19	7.E1U2.7 Standard <i>Teacher Background</i> change	Added: Info from pg. 194 from the Framework to <i>Teacher Background</i>	To address the part of 7 th 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 <i>Teacher Background</i>	Need to add information to <i>Teacher Background</i> from A Framework to address to address the function of the cell membrane.
9/25/19	7 th 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.
9/25/19	7.L2U1.12	Added: Info from pg. 144 from the Framework to <i>Teacher Background</i>	Need to add information to <i>Teacher Background</i> 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 <i>Teacher Background</i> box, to higher up in the <i>Teacher Background</i> .	To allow for better flow of information. (Like with Like)
9/25/19	8.P4U1.3	Added: Teacher Background from pg. 23 of Big Ideas	Added to further explain the transfer of energy
9/25/19	7.P3U1.4	Added: Teacher Background from pg. 115-116 A Framework	Clarify what shape and orientation means for forces
10/16/19	8.P1U1.1-2	Added: Section from page 111 from the Framework	Added from Framework to include all research when writing standards.
10/16/19	6.P2U1.4	Added: Section from page 118 from the Framework	Added from Framework to include all research when writing standards.
10/16/19	6E1U1.6	Added: Section from page 188 from the Framework	Added from Framework to include all research when writing standards.
10/19/19	Page 4- Science and Engineering Practices,	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
12/6/21	K.E1U1.3 K.E1U1.4	Added: Section from page 188 and 192 from the Framework	Added to include all research that supports the standards for clarity.
12/6/21	K.L1U1.6 K.L1U1.7	Added: Section from page 149 from the Framework	Added to include all research that supports the standards for clarity.
12/6/21	1.P2U1.1 1.P2U1.2	Added: Boundary section from page 135 the Framework	Added to include all research that supports the standards for clarity.
12/6/21	1.P3U1.3	Added: Section from page 115 from the Framework.	Added to include all research that supports the standards for clarity.

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12/6/21	1.L2U2.7 1.L2U1.8	Added: Section from page 153 from the Framework.	Added to include all research that supports the standards for clarity.
12/6/21	2.P1U1.1 2.P1U1.2	Added: Section from page 110 from the Framework.	Added to include all research that supports the standards for clarity.
12/6/21	2. P4U1.3	Added: Section from page 110 from the Framework.	Added to include all research that supports the standards for clarity.
12/6/21	2.E1U3.7	Added: Section from page 195 from the Framework.	Added to include all research that supports the standards for clarity.
12/6/21	2.E2U1.8	Added: Section from page 176 from the Framework.	Added to include all research that supports the standards for clarity.
12/7/21	3.EIU1.4	Added: Section from page 24 from Working with Big Ideas of Science Education & section from page 125 from the Framework.	Added to include all research that supports the standards for clarity.
12/7/21	3.L2U1.6	Changed coding from 3.L2U1.6 to 3.L1U1.6	Reason: The coding was incorrect. Does not align to ecosystem, aligns to structure and function.
12/7/21	3.L2U1.6	Added: Section from page 149 from the Framework.	Added to include all research that supports the standards for clarity.
12/7/21	4.P4U1.1 4.P4U1.2 4.P2U1.3 4.P4U3.4	Added: Section from page 117 & 192 from the Framework and section from page 23 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/7/21	4.E1U1.5 4.E1U1.6 4.E1U1.7 4.E1U1.8	Added: Section from page 170-180 from the Framework. Deleted: Excess information was deleted from page 135 of the Framework to avoid confusion.	Added to include all research that supports the standards for clarity.
12/7/21	4.E1U3.9 4.E1U2.10	Added: Section from page 24 from Working with Big Ideas of Science Education. Deleted: Excess information was deleted from page 155 of the Framework to avoid confusion.	Added to include all research that supports the standards for clarity.
12/8/21	5.E1U1.8	Added: Sentence from page 175 from the Framework.	Added to include all research that supports the standards for clarity.
12/8/21	6.P4U2.5	Added: Section from page 23 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/8/21	6.E2U1.7 6.E2U1.8 6.E2U1.9 6.E2U1.10	Added: Section from page 176 the Framework and section from page 21 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/8/21	6.L2U3.11 6.L2U3.12 6.L2U1.13 6.L2U1.14	Added: Section from page 153-154 & 155 from the Framework and section from page 27 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/8/21	7.P2U1.1 7.P2U1.2 7.P3U1.3	Added: Section from page 22 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/8/21	7.E1U1.5	Added: Section from page 181 & 185 from the Framework.	Added to include all research that supports the standards for clarity.

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12/8/21	7.L1U1.8 7.L1U1.9 7.L1U1.10 7.L1U1.11	Added: Sentence on page 143 was missing the Framework, added.	Added from Framework to include all research when writing standards for clarity.
12/15/21	7.L1U1.11	Removed	This background belongs with Life Science 4
12/15/21	8.P1U1.1 8.P1U1.2	Added: Section from page 108 from the Framework.	Added to include all research that supports the standards for clarity.
12/15/21	8.P4U1.3 8.P4U1.4 8.P4U1.5	Added: Section from page 124, 125-126, and 135 from the Framework.	Added to include all research that supports the standards for clarity.
12/15/21	8.E1U1.6 8.E1U3.7 8.E1U3.8	Added: Section from page 178 and 194 of the Framework. Removed section that does not belong to Big Idea of Earth Space 1.	Added to include all research that supports the standards for clarity.
12/15/21	8.L3U1.9 8.L3U3.10	Added: Section from page 164 the Framework and section from page 28 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/15/21	8.L4U1.11 8.L4U1.12	Added: Section from page 27 & 28 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/15/21	Essential HS.P1U1.2 Essential HS.P1U1.3	Added: Section from page 239 the Framework and page 20 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/21/21	Essential HS.P3.U1.6 Essential HS.P3.U2.7	Added: Section from page 22 from Working with Big Ideas of Science Education and section from page 113 the Framework.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.E1U1.13	Added: Section from page 182 & 183 the Framework.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.E1U1.13	Removed	Reason: This background belongs with Life Science 4
12/22/21	Essential HS.E1U3.14	Added: Section from page 194 & 196 from the Framework.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.E2U1.15	Added: Section from page 130 the Framework.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.E2U1.16	Added: Section from page 176 the Framework.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.E2U1.17	Added: Section from page 173 & 174 the Framework.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.L2U3.18	Added: Section from page 27 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.L2U1.21	Added: Section from page 154 the Framework.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.L2U1.24 Essential HS.L2U1.25 Essential HS.L2U3.26	Added: Section from page 158 & 159 the Framework and page 28 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.
12/22/21	Essential HS.L4U1.27 Essential HS.L4U1.28	Added: Section from page 167 the Framework and page 29 from Working with Big Ideas of Science Education.	Added to include all research that supports the standards for clarity.

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.

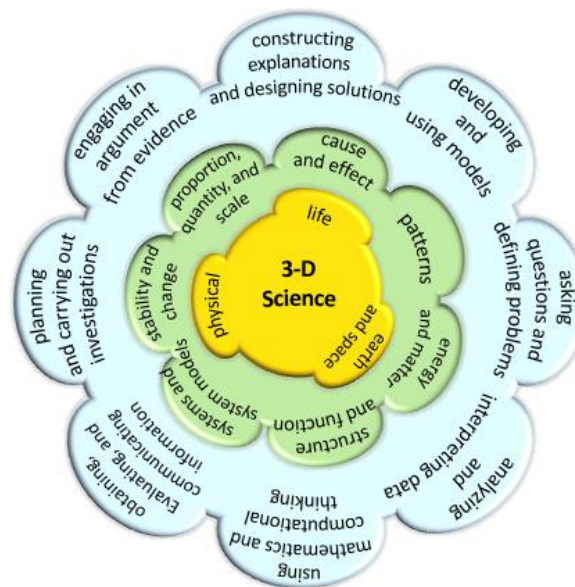


Figure 1: Three Dimensions of Science Instruction

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*
<p><u>Physical Science</u></p> <p>P1: All matter in the Universe is made of very small particles.</p> <p>P2: Objects can affect other objects at a distance.</p> <p>P3: Changing the movement of an object requires a net force to be acting on it.</p> <p>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.</p> <p><u>Earth and Space Science</u></p> <p>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.</p> <p>E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.</p> <p><u>Life Science</u></p> <p>L1: Organisms are organized on a cellular basis and have a finite life span.</p> <p>L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.</p> <p>L3: Genetic information is passed down from one generation of organisms to another.</p> <p>L4: The unity and diversity of organisms, living and extinct, is the result of evolution.</p>	<p>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.</p> <p>U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.</p> <p>U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.</p>

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

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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
<p>6.P1U1.1</p> <p>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).</p>	<p>Crosscutting Concepts: Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p>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. 108-109)</p>
<p>6.P1U1.2</p> <p>Plan and carry out an investigation to demonstrate that variations in temperature and/or pressure affect changes in state of matter.</p>	
<p>6.P1U1.3</p> <p>Develop and use models to represent that matter is made up of smaller particles called atoms.</p>	
<p>6.P2U1.4</p> <p>Develop and use a model to predict how forces act on objects at a distance.</p>	<p>Crosscutting Concepts: Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p>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</p>

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	<p>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)}</p>
<p>6.P4U2.5</p>	<p>Crosscutting Concepts and Background Information for Educators</p>
<p><u>Analyze</u> how humans use technology to store (potential) and/or use (kinetic) energy.</p>	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><u>Background Information:</u> 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. 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). ^{2 (p. 23)} 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)}</p>

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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
<p>6.E1U1.6</p> <p><u>Investigate and construct an explanation</u> demonstrating that radiation from the Sun provides energy and is absorbed to warm the Earth’s surface and atmosphere.</p>	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><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)}</p>
<p>6.E2U1.7</p> <p>Use ratios and proportions to <u>analyze and interpret data</u> related to scale, properties, and relationships among objects in our solar system.</p>	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><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 consists of the sun and a collection of objects, including planets, their moons, and asteroids</p>
<p>6.E2U1.8</p> <p><u>Develop and use models</u> to explain how constellations and other night sky patterns appear to move due to Earth’s rotation and revolution.</p>	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><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 consists of the sun and a collection of objects, including planets, their moons, and asteroids</p>

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6.E2U1.9	<p>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). 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. (p. 21) 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. (p. 176)</p>
<p>Develop and use models to construct an explanation of how eclipses, moon phases, and tides occur within the Sun-Earth-Moon system.</p>	
6.E2U1.10	
<p>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.</p>	

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	<p>Crosscutting Concepts: Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p>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.^{2(p.27)} 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</p>
<p>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.</p>	
6.L2U3.12	
<p>Engage in argument from evidence to support a claim about the factors that cause species to change and how humans can impact those factors.</p>	

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6.L2U1.13	<p>ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. 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. 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) Human activity which controls the growth of certain plants and animals changes an ecosystem.²(p.27) Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations. ⁴ (p. 155)</p> <p>Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (p. 153-154)</p>
<p><u>Develop and use models</u> to demonstrate the interdependence of organisms and their environment including biotic and abiotic factors.</p>	
6.L2U1.14	<p>ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. 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. 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) Human activity which controls the growth of certain plants and animals changes an ecosystem.²(p.27) Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations. ⁴ (p. 155)</p> <p>Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food—within an ecosystem. Transfers of matter into and out of the physical environment occur at every level—for example, when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (p. 153-154)</p>
<p><u>Construct a model</u> that shows the cycling of matter and flow of energy in ecosystems.</p>	

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 through patterns, cause and effect, and structure and function.

Core Ideas for Knowing Science*	Core Ideas for Using Science*
<p><u>Physical Science</u></p> <p>P1: All matter in the Universe is made of very small particles.</p> <p>P2: Objects can affect other objects at a distance.</p> <p>P3: Changing the movement of an object requires a net force to be acting on it.</p> <p>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.</p> <p><u>Earth and Space Science</u></p> <p>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.</p> <p>E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.</p> <p><u>Life Science</u></p> <p>L1: Organisms are organized on a cellular basis and have a finite life span.</p> <p>L2: Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.</p> <p>L3: Genetic information is passed down from one generation of organisms to another.</p> <p>L4: The unity and diversity of organisms, living and extinct, is the result of evolution.</p>	<p>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.</p> <p>U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.</p> <p>U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.</p>

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

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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	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><u>Background Information:</u> 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) All objects on the Earth are affected by gravitational forces. An object which stays at rest on the surface of the Earth has one or more forces acting on it counter balancing the force of gravity. A book lying on a table does not fall because the atoms in the table are pushing upwards on the book with a force equal to the downward force of gravity. An object floating in a liquid or in air does not move because there is an upward force balancing the downward force of gravity. The upward force is equal to the weight of the fluid displaced so heavy objects can float if they are hollowed out to displace a large weight of water. ²(p. 22)</p>
<p>Collect and analyze data demonstrating how electromagnetic forces can be attractive or repulsive and can vary in strength.</p>	
7.P2U1.2	
<p>Develop and use a model to predict how forces act on objects at a distance.</p>	
7.P3U1.3	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><u>Background Information:</u> 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</p>
<p>Plan and carry out an investigation that can support an evidence-based explanation of how objects on Earth are affected by gravitational force.</p>	
7.P3U1.4	
<p>Use non-algebraic mathematics and computational thinking to explain Newton’s laws of motion.</p>	

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	<p>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)</p>
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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	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><u>Background Information:</u> 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) The planet’s systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth’s history and will determine its future. 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)</p> <p>Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation as well as downhill flows on land. The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. ⁴(p.185)</p>
<p><u>Construct a model</u> that shows the cycling of matter and flow of energy in the atmosphere, hydrosphere, and geosphere.</p>	
7.E1U1.6	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p>
<p><u>Construct a model</u> to explain how the distribution of fossils and rocks, continental shapes, and seafloor</p>	

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<p>structures provides evidence of the past plate motions.</p>	<p><u>Background Information:</u> 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)</p>
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7.E1U2.7	Crosscutting Concepts and Background Information for Educators
<p><u>Analyze and interpret data to construct an explanation</u> for how advances in technology has improved weather prediction.</p>	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><u>Background Information:</u> 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)</p>

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	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><u>Background Information:</u> 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. Some cells in multicellular organisms, as well as</p>
<p><u>Obtain, evaluate, and communicate information</u> 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.</p>	
7.L1U1.9	

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<p><u>Construct an explanation</u> to demonstrate the relationship between major cell structures and cell functions (plant and animal).</p>	<p>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) 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) Organisms are complex, organized and built on a hierarchical structure, with each level providing the foundation for the next, from the chemical foundation of elements and atoms, to cells and systems of individual organisms to 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)</p>
<p>7.L1U1.10</p>	
<p><u>Develop and use a model</u> to explain how cells, tissues, and organ systems maintain life (animals).</p>	
<p>7.L1U1.11</p>	
<p><u>Construct an explanation</u> for how organisms maintain internal stability and evaluate the effect of the external factors on organisms’ internal stability.</p>	
<p>7.L2U1.12</p>	<p>Crosscutting Concepts and Background Information for Educators</p>
<p><u>Construct an explanation</u> for how some plant cells convert light energy into food energy.</p>	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p><u>Background Information:</u> 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. 147-148)</p>

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*
<p><u>Physical Science</u></p> <p>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.</p> <p><u>Earth and Space Science</u></p> <p>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.</p> <p><u>Life Science</u></p> <p>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.</p>	<p>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.</p> <p>U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.</p> <p>U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.</p>

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

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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
<p>8.P1U1.1</p> <p>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.</p>	<p>Crosscutting Concepts: Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p>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) Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. All substances are made from some 100 different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. ⁴ (p. 108) 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)</p>
<p>8.P1U1.2</p> <p>Obtain and evaluate information regarding how scientists identify substances based on unique physical and chemical properties.</p>	
<p>8.P4U1.3</p>	<p>Crosscutting Concepts and Background Information for Educators</p>
<p>Construct an explanation on how energy can be transferred from one energy store to another.</p>	<p>Crosscutting Concepts: Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p>Background Information: The total change of energy in any system is always equal to the total energy transferred into or out of the system. This is called conservation of energy. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. ⁴ (p. 124) When the motion energy of an object changes, there is inevitably some other change in energy at the same time. For example, the friction that causes a moving object to stop also results in an increase in the thermal energy in both surfaces; eventually heat energy is transferred to the surrounding environment as the surfaces cool. Similarly, to make an</p>
<p>8.P4U1.4</p> <p>Develop and use mathematical models to explain wave characteristics and interactions.</p>	

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8.P4U2.5

Develop a solution to increase efficiency when transferring energy from one source to another.

object start moving or to keep it moving when friction forces transfer energy away from it, energy must be provided from, say, chemical (e.g., burning fuel) or electrical (e.g., an electric motor and a battery) processes.

The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation. ⁴ (p. 125-126) 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) When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. Lenses and prisms are applications of this effect. A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (prisms). However, because light can travel through space, it cannot be a matter wave, like sound or water waves. ⁴ (p. 135)

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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
<p>8.E1U1.6</p> <p>Analyze and interpret data about the Earth’s geological column to communicate relative ages of rock layers and fossils.</p>	<p>Crosscutting Concepts: Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p> <p>Background Information: The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analysis of rock strata and the fossil record provide only relative dates, not an absolute scale. ⁴ (p. 178) 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, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus they are not yet predictable. However, 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) 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. ⁴ (p. 196)</p>
<p>8.E1U3.7</p> <p>Obtain, evaluate, and communicate information about data and historical patterns to predict natural hazards and other geological events.</p>	
<p>8.E1U3.8</p> <p>Construct and support an argument about how human consumption of limited resources impacts the biosphere.</p>	

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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
<p>8.L3U1.9</p> <p>Construct an explanation of how genetic variations occur in offspring through the inheritance of traits or through mutations.</p>	<p>Crosscutting Concepts: Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p>
<p>8.L3U3.10</p> <p>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.</p>	<p>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) 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) The sorting and recombining of genetic material when egg and sperm cells are formed and then fuse results in an immense variety of possible combinations of genes, and in differences that can be inherited from one generation to another. These provide the potential for natural selection as a result of some variations making organisms better adapted to certain environmental conditions. ² (p. 28)</p>

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<p>8.L4U1.11</p>	<p>Crosscutting Concepts and Background Information for Educators</p>
<p><u>Develop and use a model</u> to explain how natural selection may lead to increases and decreases of specific traits in populations over time.</p>	<p><u>Crosscutting Concepts:</u> Patterns; Cause and Effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Structure and Function; Stability and Change⁴</p>
<p>8.L4U1.12</p>	<p><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)} 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)} The sorting and recombining of genetic material when egg and sperm cells are formed and then fuse results in an immense variety of possible combinations of genes, and in differences that can be inherited from one generation to another. These provide the potential for natural selection as a result of some variations making organisms better adapted to certain environmental conditions. ^{2 (p. 28)}</p>
<p><u>Gather and communicate evidence</u> on how the process of natural selection provides an explanation of how new species can evolve.</p>	

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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		

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

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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	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

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	and data collected are used to test existing theories and explanations or to revise and develop new ones.	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.

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<p>Engage in Argument from Evidence</p>	<p>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.</p>	<p>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.</p>
<p>Obtain, Evaluate, and Communicate Information</p>	<p>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.</p>	<p>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.</p>

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

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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.

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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.

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Core Ideas for Using Science	
<p>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.</p>	<p>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)}</p> <p>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)}</p>
<p>U2: The knowledge produced by science is used in engineering and technologies to solve problems and/or create products.</p>	<p>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)}</p>
<p>U3: Applications of science often have both positive and negative ethical, social, economic, and/or political implications.</p>	<p>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)}</p>

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 communities⁴.

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 discourse⁶. 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 ways². Science teachers need to acquire effective strategies to include all students regardless of age, racial, ethnic, cultural, linguistic, socioeconomic, and gender backgrounds³.

Effective teaching strategies³ 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 connections⁸.
- **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.

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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.

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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.

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Appendix 6: Connections to English Language Arts and Math

Kindergarten - 2nd Grade

	Kindergarten	1st Grade	2nd Grade
<u>Arizona English Language Arts</u>	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		
<u>Arizona Mathematics Standards</u>	<p>Standards for Mathematical Practices</p> <ul style="list-style-type: none"> -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 <p>Counting and Cardinality</p> <ul style="list-style-type: none"> -Develop competence with counting and cardinality -Develop understanding of addition and subtraction within 10 <p>Measurement and Data</p> <ul style="list-style-type: none"> -Describe and compare measurable attributes -Classify objects and count the number of objects in each category 	<p>Standards for Mathematical Practice</p> <ul style="list-style-type: none"> -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 <p>Measurement and Data</p> <ul style="list-style-type: none"> -Measure lengths indirectly and by iterating length units -Represent and interpret data <p>Geometry</p> <ul style="list-style-type: none"> -Reason with shapes and their attribute 	<p>Standards for Mathematical Practice</p> <ul style="list-style-type: none"> -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 <p>Operations and Algebraic Thinking</p> <ul style="list-style-type: none"> -Represent and solve problems involving addition and subtraction <p>Number and Operations in Base Ten</p> <ul style="list-style-type: none"> -Use place value understanding and properties of operations to add and subtract <p>Measurement and Data</p> <ul style="list-style-type: none"> -Represent and interpret data -Measure the length of an object using an appropriate tool including metrics.

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3rd Grade - 5th Grade

	3rd Grade	4th Grade	5th Grade
<u>Arizona English Language Arts</u>	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		
<u>Arizona Mathematics Standards</u>	<p>Standards for Mathematical Practices</p> <ul style="list-style-type: none"> -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 <p>Operations and Algebraic Thinking</p> <ul style="list-style-type: none"> -Represent and solve problems involving addition and subtraction <p>Number and Operations in Base Ten</p> <ul style="list-style-type: none"> -Use place value understanding and properties of operations to perform multi-digit arithmetic <p>Number and Operations - Fractions</p> <ul style="list-style-type: none"> -Understand fractions as numbers <p>Measurement and Data</p> <ul style="list-style-type: none"> -Measure and estimate liquid volumes and masses of objects -Solve problems involving measurement -Represent and interpret data 	<p>Standards for Mathematical Practice</p> <ul style="list-style-type: none"> -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 <p>Operations and Algebraic Thinking</p> <ul style="list-style-type: none"> -Use place value understanding and properties of operations to perform multi-digit arithmetic <p>Number and Operations in Base Ten</p> <p>Number and Operations - Fractions</p> <ul style="list-style-type: none"> -Understand decimal notation for fractions and compare decimal fractions <p>Measurement and Data</p> <ul style="list-style-type: none"> -Solve problems involving measurement and conversion of measurements from a larger unit to a smaller unit -Represent and interpret data 	<p>Standards for Mathematical Practice</p> <ul style="list-style-type: none"> -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 <p>Operations and Algebraic Thinking</p> <ul style="list-style-type: none"> -Write and interpret numerical expressions. -Analyze patterns and relationships <p>Measurement and Data</p> <ul style="list-style-type: none"> -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.

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6th Grade - 8th Grade

	6th Grade	7th Grade	8th Grade
<u>Arizona English Language Arts</u>	Use age-appropriate scientific texts and biographies to develop instruction surrounding the Reading Standards for Informational Text, and the Writing Standards		
<u>Arizona Mathematics Standards</u>	<p>Standards for Mathematical Practices</p> <ul style="list-style-type: none"> -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 <p>Ratios and Proportional Relationships</p> <ul style="list-style-type: none"> -Understand ratio concepts and use ratio reasoning to solve problems <p>Expressions and Equations</p> <ul style="list-style-type: none"> -Represent and analyze quantitative relationships between dependent and independent variable <p>Geometry</p> <ul style="list-style-type: none"> -Solve mathematical problems and problems in real-world context involving area, surface area and volume 	<p>Standards for Mathematical Practice</p> <ul style="list-style-type: none"> -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 <p>Statistics and Probability</p> <ul style="list-style-type: none"> -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 	<p>Standards for Mathematical Practice</p> <ul style="list-style-type: none"> -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 <p>Expressions and Equations</p> <ul style="list-style-type: none"> -Understand the connections between proportional relationships, lines, and linear equations <p>Functions</p> <ul style="list-style-type: none"> -Use functions to model relationships between quantities <p>Statistics and Probability</p> <ul style="list-style-type: none"> -Investigate patterns of association in bivariate data -Investigate chance processes and develop, use, and evaluate probability models

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