Arizona Science Standards
2018

Arizona Department of Education
High Academic Standards for Students
High School

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 events or situations that are observed to exist or happen, especially phenomena whose causes or explanations are in question. Science sense-making 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 fourteen core ideas and develop learning progressions to coherently and logically build scientific literacy from kindergarten through high school.
- Connect **core ideas**, **crosscutting concepts**, and **science and engineering practices**, to make sense of the natural world and understand how science and engineering are practiced and experienced.
- Focus on fewer, broader standards that allow for greater depth, more connections, deeper understanding, and more applications of content.

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

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

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

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

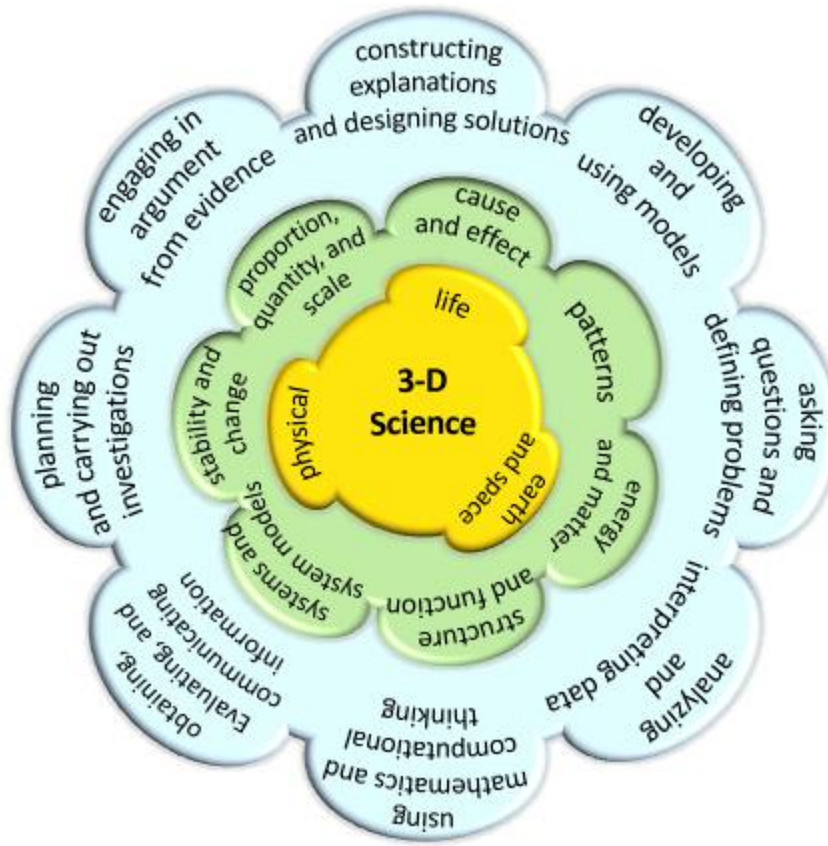


Figure 1: Three Dimensions of Science Instruction

Science and Engineering Practices

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

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

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

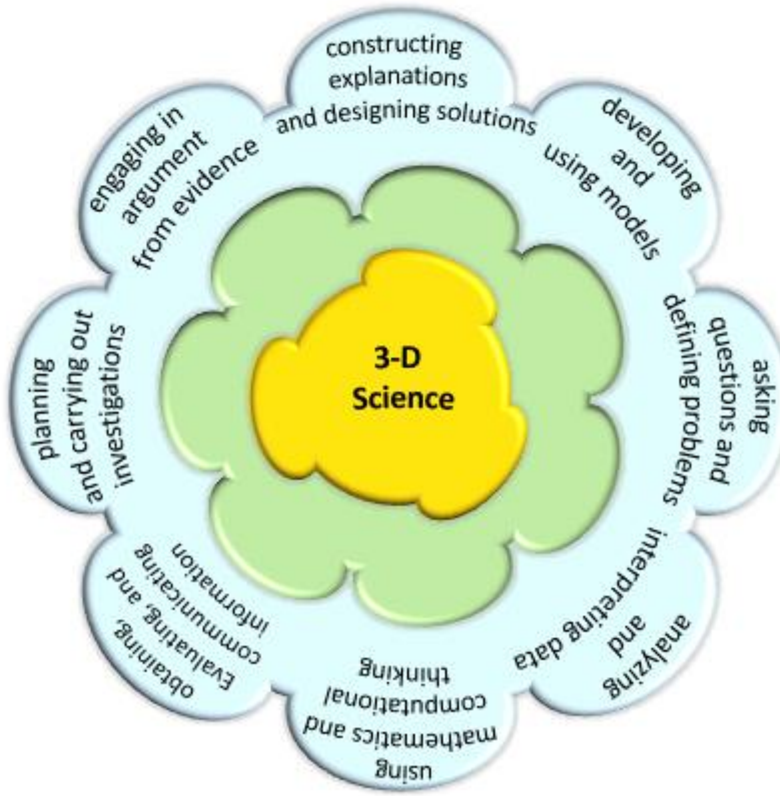


Figure 2: Science and engineering practices are used to

Crosscutting Concepts

Crosscutting concepts[4] cross boundaries between science disciplines and provide an organizational framework to connect knowledge from various disciplines into a coherent and scientifically based view of the world. They bridge boundaries 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.

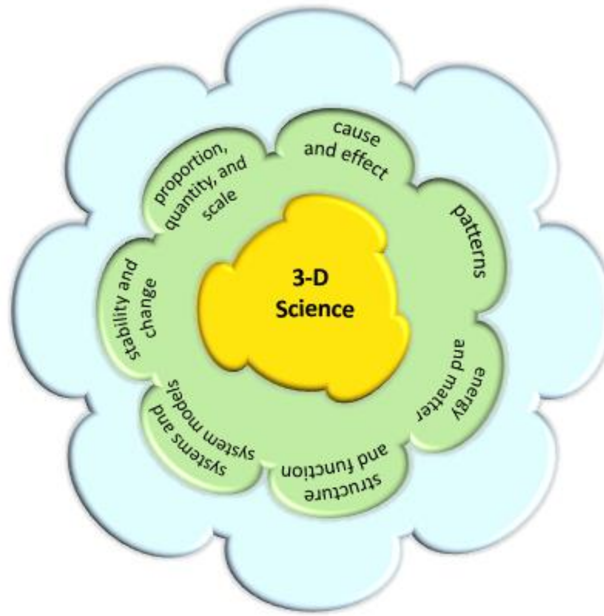


Figure 3: Crosscutting concepts provide a lens for understanding the core ideas

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.

Core Ideas

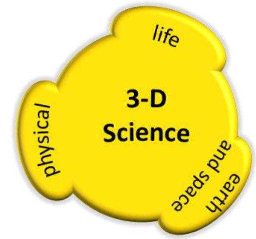


Figure 4: Core ideas for knowing science and using science develop scientific literacy through science content knowledge, understanding the nature of science, applications of science and engineering, and social implications

The Arizona Science Standards focus on fourteen 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 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.

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

Time Allotment

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

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

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

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

Safety Expectations

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

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

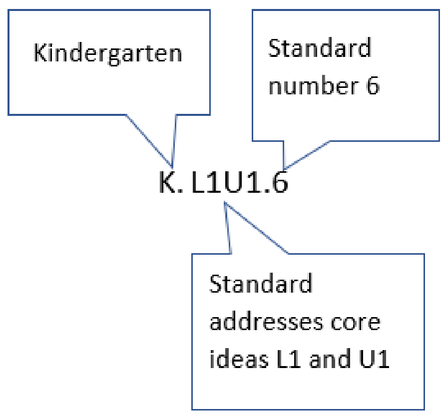
Chemical Storage Expectations

What You Can Do

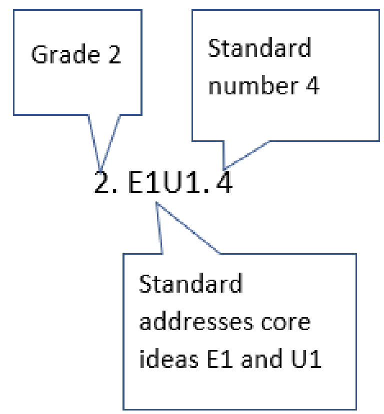
- Put in place an experienced leadership team to oversee chemical management, storage, and handling activities.
- Implement pollution prevention and green chemistry (safer alternatives) principles to minimize the use of hazardous chemicals at schools.
- Establish an environmentally preferable purchasing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

Coding of the K-8 Science Standards

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



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



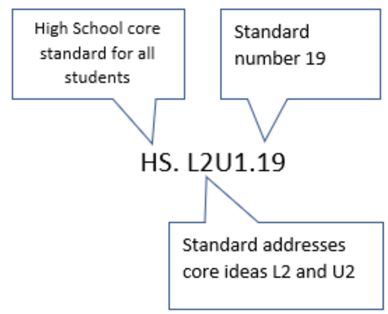
2.E1U1.4. Observe and investigate how wind and water change the shape of the land resulting in a variety of landforms.

Coding of the High School Science Standards

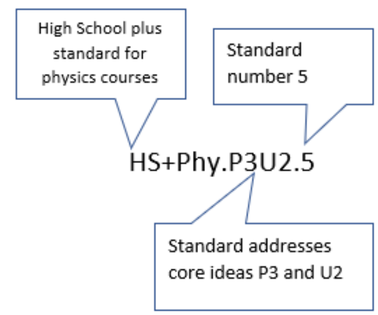
In Arizona, students are required to take 3 credits of high school science aligned to standards in physical, earth and space, and life sciences to meet graduation requirements, but there is no mandatory course sequence across the state. Because of this, the high school standards are written at two levels: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

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

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



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



HS+Phy.P3U2.6. 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
Life Science Standards	**Learning Progressions, Key Terms, and Crosscutting Concepts**
1.L2U2.7	
Develop and use models about how living things use resources to grow and survive; **design and evaluate** habitats for organisms using earth materials.	**Animals** depend on their surroundings to get what they need, including **food**, **water**, **shelter**, and a **favorable temperature**. Animals depend on **plants** or other animals for food. They use their **senses** to find food and water, and they use their **body parts** to gather, catch, eat, and chew the food. Plants depend on **air**, water, **minerals** (in the soil), and **light** to grow. Animals can move around, but plants cannot, and they often depend on animals for pollination or to move their seeds around. Different plants survive better in different settings because they have varied needs for water, minerals, and sunlight [4](, 151) Crosscutting Concepts: **cause and effect;** systems and system models; energy and matter; structure and function; **stability and change** [4]
1.L2U1.8	
Construct an explanation describing how organisms obtain resources from the environment including materials that are used again by other organisms. Concepts taught in K.L1U1.5, K.L4U2.7	

Guide to Explain Standards

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

High School Science Standards

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

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

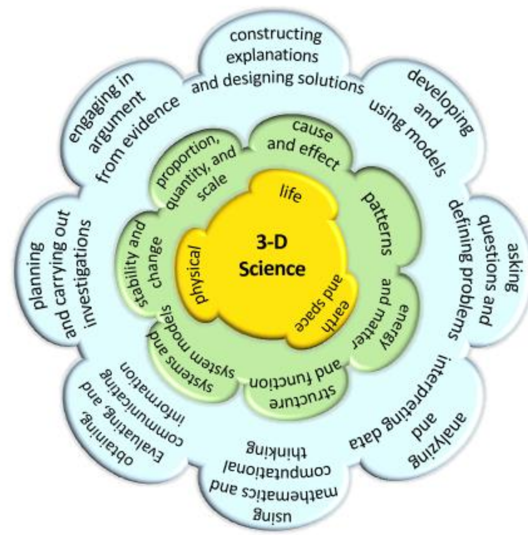


Figure 1: Three Dimensions of Science Instruction

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

High School Physical Sciences

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

Note:

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

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

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

Structures and Properties of Matter

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

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

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

Chemical Reactions

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

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

Chemistry – P1: All matter in the Universe is made of very small particles. **Nuclear Processes and Applications of Chemistry** Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.	
Essential HS.P1U3.4 **Obtain, evaluate, and communicate information** about how the use of chemistry related technologies have had positive and negative ethical, social, economic, and/or political implications. Physical Science Plus (+) Standards HS+C are supporting standards designed to be used with the essential standards for students taking a high school chemistry (C) course. **Plus HS+C.P1U3.8** **Engage in argument from evidence** regarding the ethical, social, economic, and/or political benefits and liabilities of fission, fusion, and radioactive decay.	Scientific understanding can help to identify implications of certain applications but decisions about whether certain actions should be taken will require **ethical and moral judgements** which are not provided by knowledge of science. There is an important difference between the understanding that science provides about, for example, the need to preserve biodiversity, the factors leading to climate change and the adverse effects of harmful substances and lifestyles, and the actions that may or may not be taken in relation to these issues. Opinions may vary about what action to take but arguments based on scientific evidence should not be a matter of opinion. [2 (p. 33)] The total number of neutrons plus protons does not change in any **nuclear process**. Strong and weak nuclear interactions determine nuclear stability and processes. Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present. [4 (p. 113)] Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

Physics – P2: Objects can affect other objects at a distance. **Motion & Stability – Forces & Interactions** Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.	
Essential HS.P2U1.5 Construct an explanation for a field's strength and influence on an object (electric, gravitational, magnetic). Physical Science Plus (+) Standards HS+P are supporting standards designed to be used with the essential standards for students taking a high school physics (P) course. **Plus HS+Phy.P2U1.1** Plan and carry out investigations to design, build, and refine a device that works within given constraints to demonstrate that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.	**Newton's law of universal gravitation** and **Coulomb's law** provide the mathematical models to describe and predict the effects of **gravitational** and **electrostatic forces** between distant objects. Forces at a distance are explained by fields permeating space that can transfer energy through space. **Magnets** or changing electric fields cause magnetic fields; electric charges or changing magnetic fields cause electric fields. [4 (p. 116)] **Newton's second law** accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. **Momentum** is defined for a particular frame of reference; it is the **mass** times the **velocity** of the object. In any system, total momentum is always **conserved**. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.[4 (p. 116)] The application of science in making new materials is an example of how scientific knowledge has led advances in technology and provided engineers with a wider choice in designing constructions. At the same time technological advances have helped scientific developments by improving instruments for observation and measuring, automating processes that might otherwise be too dangerous or time consuming to undertake, and particularly through the provision of computers. Thus, **technology aids scientific advances** which in turn can be used in **designing and making things for people to use**. [2 (p. 32)] Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

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

Motion & Stability – Forces & Interactions

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

Essential HS.P3U1.6
Collect, analyze and interpret data regarding the change in motion of an object or system in one dimension, to construct an explanation using Newton's Laws.

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

Plus HS+Phy.P3U1.2
Develop and use mathematical models of Newton's law of gravitation and Coulomb's law to describe and predict the gravitational and electrostatic forces between objects.

Plus HS+Phy.P3U1.3
Develop **a** mathematical model**, us**ing Newton's laws, to predict the motion of an object or system in two dimensions (projectile and circular motion).

Plus HS+Phy.P3U1.4
Engage in argument from evidence regarding the claim that the total momentum of a system is conserved when there is no net force on the system.

Essential HS.P3U2.7
Use mathematics and computational thinking to explain how Newton's laws are used in engineering and technologies to create products to serve human ends.

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

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

Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

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

Energy & Waves

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

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

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

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

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

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

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

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

Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

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

High School Earth and Space Sciences

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

Note:

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

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

Earth and Space – E1: The composition of the Earth and its atmosphere and the natural and human processes occurring within them shape the Earth's surface and its climate. **Weather & Climate** Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.	
Essential HS.E1U1.11 Analyze and interpret data to determine how energy from the Sun affects weather patterns and climate.	**Learning Progressions, Key Terms and Crosscutting Concepts** **Weather**, which varies from day to day and seasonally throughout the year, is the condition of the atmosphere at a given place and time. **Climate** is longer term and location sensitive; it is the range of a region's weather over 1 year or many years, and, because it depends on latitude and geography, it varies from place to place.[4 (186)] The foundation for Earth's global climate system is the **electromagnetic radiation** from the sun as well as its **reflection, absorption, storage, and redistribution** among the **atmosphere, ocean, and land systems** and this energy's reradiation into space. **Climate change** can occur when certain parts of Earth's systems are altered. **Geological evidence** indicates that past climate changes were either sudden changes caused by **alterations in the atmosphere**; **longer term changes** (e.g., ice ages) due to variations in solar output, Earth's orbit, or the orientation of its axis; or even **more gradual atmospheric changes** due to plants and other organisms that captured carbon dioxide and released oxygen. The time scales of these changes varied from a few to millions of years.[4 (188)] Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]
Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course.	
Plus HS+E.E1U1.1 Construct an explanation based on evidence for how the Sun's energy transfers between Earth's systems.	
Plus HS+E.E1U1.2 Develop and use models to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.	
Plus HS+E.E1U1.3 Analyze geoscience **data** and the results from global climate models to make evidence-based predictions of current rate and scale of global or regional climate changes.	

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

Roles of Water in Earth's Surface Processes

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

Standards	Learning Progressions, Key Terms and Crosscutting Concepts
Essential HS.E1U1.12 Develop and use models of the Earth that explains the role of energy and matter in Earth's constantly changing internal and external systems (geosphere, hydrosphere, atmosphere, biosphere). Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course. **Plus HS+E.E1U1.4** Analyze and interpret geoscience **data** to make the claim that dynamic interactions with Earth's surface can create feedbacks that cause changes to other Earth systems. **Plus HS+E.E1U1.5** Obtain, evaluate, and communicate information on the effect of water on Earth's materials, surface processes, and groundwater systems.	Earth's systems, being dynamic and interacting, cause **feedback effects** that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts. Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but **solid inner core**, a **liquid outer core**, a **solid mantle** and **crust**. The top part of the mantle, along with the crust, forms structures known as **tectonic plates** (link to ESS2.B). Motions of the mantle and its plates occur primarily through **thermal convection**, which involves the **cycling of matter** due to the outward flow of energy from Earth's interior and the gravitational movement of denser materials toward the interior. The **geological record** shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities. These changes can occur on a variety of time scales from sudden (e.g., volcanic ash clouds) to intermediate (ice ages) to very long-term tectonic cycles. [4 (p. 181)] The **abundance of liquid water** on Earth's surface and its **unique combination of physical and chemical properties** are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks. [4 (pp. 185-186)] Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

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

Earth's Systems

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

Essential HS.E1U1.13

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

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

Plus HS+E.E1U1.6

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

Plus HS+E.E1U1.7

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

Plus HS+E.E1U1.8

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

Learning Progressions, Key Terms and Crosscutting Concepts

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

Crosscutting Concepts: Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change [4]

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

Earth and Human Activity

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

Standards	Learning Progressions, Key Terms and Crosscutting Concepts
Essential HS.E1U3.14 Engage in argument from evidence about the availability of natural resources, occurrence of natural hazards, changes in climate, and human activity and how they influence each other. Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course. **Plus HS+E.E1U3.9** Construct an explanation, **based on evidence,** for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. **Plus HS+E.E1U3.10** Ask questions, define problems, and evaluate a solution to a complex problem, based on prioritized criteria and tradeoffs, that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. **Plus HS+E.E1U3.11** Develop and use a quantitative model to illustrate the relationship among Earth systems and the degree to which those relationships are being modified due to human activity.	**Learning Progressions, Key Terms and Crosscutting Concepts** Changes in the atmosphere due to **human activity** have increased **carbon dioxide** concentrations and thus affect climate (link to ESS3.D). 4 (188) **Global climate models** are often used to understand the process of climate change because these changes are complex and can occur slowly over Earth's history. Though the magnitudes of humans' impacts are greater than they have ever been, so too are humans' abilities to model, predict, and manage current and future impacts.4 (198) Materials important to modern technological societies are not uniformly distributed across the planet (e.g., oil in the Middle East, gold in California). Most elements exist in Earth's crust at concentrations too low to be extracted, but in some locations—where geological processes have concentrated them—**extraction** is economically viable. Historically, humans have populated regions that are climatically, hydrologically, and geologically advantageous for fresh water availability, food production via agriculture, commerce, and other aspects of civilization. **Resource availability** affects geopolitical relationships and can limit development. As the global human population increases and people's demands for better living conditions increase, resources considered readily available in the past, such as land for agriculture or drinkable water, are becoming scarcer and more valued. All forms of resource extraction and land use have associated economic, social, environmental, and geopolitical **costs and risks**, as well as **benefits**. New technologies and regulations can change the balance of these factors. Much energy production today comes from **nonrenewable sources**, such as coal and oil. However, advances in related science and technology are reducing the cost of energy from **renewable resources**, such as sunlight. As a result, future energy supplies are likely to come from a much wider range of sources. 4 (191-192) Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

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

Earth's Place in the Universe

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

Essential HS.E2U1.15 **Construct an explanation** based on evidence to illustrate the role of nuclear fusion in the life cycle of a star.	**Learning Progressions, Key Terms and Crosscutting Concepts** Our Sun is one of many stars that make up the Universe, essentially made of hydrogen. The source of energy that the Sun and all stars radiate comes from **nuclear reactions** in their central cores. The Sun is one of millions of stars that together make up a galaxy called the Milky Way. 2 (p. 25) Nearly all observable matter in the universe is hydrogen or helium, which formed in the first minutes after the Big Bang. Elements other than these remnants of the Big Bang continue to form within the cores of stars. **Nuclear fusion** within stars produces all atomic nuclei lighter than and including iron, and the process releases the energy seen as starlight. Heavier elements are produced when certain massive stars achieve a **supernova** stage and explode. 4 (p. 173) Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function[4]
Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course.	
Plus HS+E.E2U1.12 **Obtain, evaluate, and communicate scientific information** about the way stars, throughout their stellar stages, produce elements and energy	

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

Earth and the Solar System

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

Essential HS.E2U1.16 **Construct an explanation** of how gravitational forces impact the evolution of planetary motion, structure, surfaces, atmospheres, moons, and rings.	**Learning Progressions, Key Terms and Crosscutting Concepts** Planetary motions around the sun can be predicted **using Kepler's three empirical laws**, which can be explained based on **Newton's theory of gravity.** These orbits may also change somewhat due to the **gravitational effects** from, or collisions with, other bodies. 4 (p. 175) Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function[4]
Earth and space Plus (+) Standards HS+E are supporting standards designed to be used with the essential standards for students taking a high school earth and space (E) course.	
Plus HS+E.E2U1.13 **Analyze and interpret data** showing how gravitational forces are influenced by mass, and the distance between objects.	
Plus HS+E.E2U1.14 **Use mathematics and computational thinking** to explain the movement of planets and objects in the solar system.	

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

The Universe and its Stars

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

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

High School Life Sciences

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

Note:

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

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

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

Ecosystems

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

Essential HS.L2U3.18

Obtain, evaluate, and communicate about the positive and negative ethical, social, economic, and political implications of human activity on the biodiversity of an ecosystem.

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

Plus HS+B.L2U1.1

Develop a model showing the relationship between limiting factors and carrying capacity, and use the model to make predictions on how environmental changes impact biodiversity.

Plus HS+B.L4U1.2

Engage in argument from evidence that changes in environmental conditions or human interventions may change species diversity in an ecosystem.

Learning Progressions, Key Terms and Crosscutting Concepts

A complex set of **interactions** within an **ecosystem** can keep its numbers and types of **organisms** relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and **habitat** availability. Moreover, **anthropogenic changes** (induced by human activity) in the environment —including habitat destruction, **pollution**, introduction of **invasive species**, **overexploitation**, and **climate change** —can disrupt an ecosystem and threaten the survival of some **species.** [4 (pp. 155-156)] Ecosystems have **carrying capacities**, which are **limits** to the numbers of organisms and populations they can support. These limits result from such **factors** as the availability of living and nonliving resources and from such challenges as **predation, competition**, and **disease**. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and **resources are finite**. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. [4 (p. 152)] **Biodiversity** is increased by the formation of new species (**speciation**) and decreased by the loss of species (**extinction**). Biological extinction, being irreversible, is a critical factor in reducing the planet's natural capital. Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is having positive and negative impacts on biodiversity through **overpopulation**, **overexploitation**, **habitat destruction, pollution, introduction of invasive species, and climate change**. These problems have the potential to cause a major wave of biological extinctions—as many species or populations of a given species, unable to survive in changed environments, die out—and the effects may be harmful to humans and other living things. Thus sustaining biodiversity so that **ecosystem** functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. [4 (p. 167)]

Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

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

Ecosystems

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

Essential HS.L2U1.19

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

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

Plus HS+B.L2U1.3

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

Learning Progressions, Key Terms and Crosscutting Concepts

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

Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

Life Science – L1: Organisms are organized on a cellular basis and have a finite life span. **Cells & Organisms** Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.	
Essential HS.L1U1.20 Ask questions **and/or make predictions** based on observations and evidence to demonstrate how cellular organization, structure, and function allow organisms to maintain homeostasis.	**Learning Progressions, Key Terms and Crosscutting Concepts** Within cells there are many molecules of different kinds which interact in carrying out the functions of the cell. In multicellular organisms **cells communicate** with each other by passing substances to nearby cells to coordinate activity. A **membrane** around each cell plays an important part in **regulating what can enter or leave a cell**. Activity within different types of cells is regulated by **enzymes**. [2 (p. 26)] Systems of specialized cells within organisms help them perform the essential functions of life, which involve chemical reactions that take place between different types of molecules, such as **water**, **proteins, carbohydrates, lipids,** and **nucleic acids**. Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. **Feedback mechanisms** maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some **range**. Outside that range (e.g., at a too high or too low external temperature, with too little food or water available), the organism cannot survive. Feedback mechanisms can encourage (through **positive feedback**) or discourage (**negative feedback**) what is going on inside the living system. [4 (p. 145)] Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]
Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course.	
Plus HS+B.L1U1.4 **Develop and use models** to explain the interdependency and interactions between cellular organelles.	
Plus HS+B.L1U1.5 **Analyze and interpret data** that demonstrates the relationship between cellular function and the diversity of protein functions.	
Plus HS+B.L1U1.6 **Develop and use models** to show how transport mechanisms function in cells.	
Plus HS+B.L1U1.7 **Develop and use models** to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms (plant and animal).	

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

Cells & Organisms

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

Essential HS.L2U1.21

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

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

Plus HS+B.L2U1.8

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

Learning Progressions, Key Terms and Crosscutting Concepts

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

Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

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

Cells and Organisms

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

Standards	Learning Progressions, Key Terms and Crosscutting Concepts
Essential HS.L1U1.22 **Construct an explanation** for how cellular division (mitosis) is the process by which organisms grow and maintain complex, interconnected systems. **Essential HS.L1U3.23** **Obtain, evaluate, and communicate** the ethical, social, economic and/or political implications of the detection and treatment of abnormal cell function. Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course. **Plus HS+B.L1U1.9** **Develop and use a model** to **communicate** how a cell copies genetic information to make new cells during asexual reproduction (mitosis).	In multicellular organisms individual cells grow and then divide via a process called **mitosis**, thereby allowing the organism to grow. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. [4] (pp. 146-147) Given a suitable medium, cells from a variety of organisms can be grown in situ, that is, outside the organism. These **cell cultures** are used by scientists to investigate cell functions and have medical implications such as the **production of vaccines, screening of drugs**, and **in vitro fertilization**. Plant tissue culture is used widely in the plant sciences, forestry, and in horticulture. Most cells are programmed for a limited number of cell divisions. Diseases, which may be caused by invading microorganisms, environmental conditions or defective cell programming, generally result in **disturbed cell function**. Organisms die if their cells are incapable of further division. 2 (p. 26) Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

Life Science – L3: Genetic information is passed down from one generation of organisms to another. Genetics Essential standards are standards that will be assessed on the state exam and are intended for ALL students to have learned by the end of 3 credits of high school science courses.	
Essential HS.L3U1.24 Construct an explanation of how the process of sexual reproduction contributes to genetic variation. **Essential HS.L3U1.25** Obtain, evaluate, and communicate **information** about the causes and implications of DNA mutation. **Essential HS.L3U3.26** Engage in argument from evidence regarding the ethical, social, economic, and/or political implications of a current genetic technology. Life Science Plus (+) Standards HS+B are supporting standards designed to be used with the essential standards for students taking a high school biology (B) course. **Plus HS+B.L3U1.10** Use mathematics and computational thinking to explain the variation that occurs through meiosis and calculate the distribution of expressed traits in a population. **Plus HS+B.L3U1.11** Construct an explanation for how the structure of DNA and RNA determine the structure of proteins that perform essential life functions. **Plus HS+B.L3U1.12** Analyze and interpret data on how mutations can lead to increased genetic variation in a population.	**Learning Progressions, Key Terms and Crosscutting Concepts** In **sexual reproduction**, a specialized type of cell division called **meiosis** occurs and results in the production of sex cells, such as **gametes** (**sperm and eggs**) or **spores**, which contain only one member from each **chromosome pair** in the parent cell. 4 (pp. 147) The information passed from parents to offspring is coded in the **DNA** molecules that form the **chromosomes**. In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more **genetic variation**. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in **mutations**, which are also a source of genetic variation. **Environmental factors** can also cause mutations in genes, and viable mutations are inherited. Environmental factors also affect **expression of traits**, and hence affect the **probability** of occurrences of traits in a population. Thus the variation and distribution of traits observed depend on both **genetic and environmental factors**. 4 (p. 147) The overall sequence of genes of an organism is known as its **genome**. More is being learned all the time about genetic information by **mapping the genomes** of different kinds of organisms. When sequences of genes are known genetic material can be **artificially changed** to give organisms certain features. In **gene therapy** special techniques are used to deliver into human cells genes that are beginning to help in curing disease. 2 (p. 28) Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function 4 Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function 4

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

Evolution

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

Essential HS.L4U1.27

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

Essential HS.L4U1.28

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

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

Plus HS+B.L4U1.13

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

Plus HS+B.L4U1.14

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

Learning Progressions, Key Terms and Crosscutting Concepts

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

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

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

Crosscutting Concepts: Patterns; Cause and effect; Scale, Proportion and Quantity; Systems and System Models; Energy and Matter; Stability and change; Structure and function [4]

Distribution of High School Standards; essential standards (HS) and course-specific plus (HS+)	U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	U2: The knowledge produced by science is used in engineering and technologies to create products.	U3: Applications of science often have both positive and negative ethical, social, economic, and political implications.
P1: All matter in the Universe is made of very small particles.	**Essential HS.P1U1.1** **Plus HS+C.P1U1.1** **Plus HS+C.P1U1.2** **Plus HS+C.P1U1.3** **Essential HS.P1U1.2** **Essential HS.P1U1.3** **Plus HS+C.P1U1.4** **Plus HS+C.P1U1.5** **Plus HS+C.P1U1.6** **Plus HS+C.P1U1.7**		**Essential HS.P1U3.4** **Plus HS+C.P1U3.8**
P2: Objects can affect other objects at a distance.	**Essential HS.P2U1.5** **Plus HS+Phy.P2U1.1**		
P3: Changing the movement of an object requires a net force to be acting on it.	**Essential HS.P3U1.6** **Plus HS+Phy.P3U1.2** **Plus HS+Phy.P3U1.3** **Plus HS+Phy.P3U1.4**	**Essential HS.P3U2.7** **Plus HS+Phy.P3U2.5**	
P4: The total amount of energy in a closed system is always the same but can be transferred from one energy store to another during an event.	**Essential HS.P4U1.8** **Essential HS.P4U3.9** **Plus HS+Phy.P4U1.6** **Plus HS+Phy.P4U2.7** **Plus HS+Phy.P4U1.8** **Essential HS.P4U1.10**		
E1: The composition of the Earth and its atmosphere and the natural and human	**Essential HS.E1U1.11** **Plus HS+E.E1U1.1**		**Essential HS.E1U3.14** **Plus HS+E.E1U3.9**

Distribution of High School Standards; essential standards (HS) and course-specific plus (HS+)	U1: Scientists explain phenomena using evidence obtained from observations and or scientific investigations. Evidence may lead to developing models and or theories to make sense of phenomena. As new evidence is discovered, models and theories can be revised.	U2: The knowledge produced by science is used in engineering and technologies to create products.	U3: Applications of science often have both positive and negative ethical, social, economic, and political implications.
processes occurring within them shape the Earth's surface and its climate.	**Plus HS+E.E1U1.2** **Plus HS+E.E1U1.3** **Essential HS.E1U1.12** **Plus HS+E.E1U1.4** **Plus HS+E.E1U1.5** **Essential HS.E1U1.13** **Plus HS+E.E1U1.6** **Plus HS+E.E1U1.7** **Plus HS+E.E1U1.8**		**Plus HS+E.E1U3.10** **Plus HS+E.E1U3.11**
E2: The Earth and our solar system are a very small part of one of many galaxies within the Universe.	**Essential HS.E2U1.15** **Plus HS+E.E2U1.12** **Essential HS.E2U1.16** **Plus HS+E.E2U1.13** **Plus HS+E.E2U1.14** **Essential HS.E2U1.17** **Plus HS+E.E2U1.15** **Plus HS+E.E2U1.16**	**Plus HS+E.E2U2.17**	
L1: Organisms are organized on a cellular basis and have a finite life span.	**Essential HS.L1U1.20** **Plus HS+B.L1U1.4** **Plus HS+B.L1U1.5** **Plus HS+B.L1U1.6** **Plus HS+B.L1U1.7** **Essential HS.L1U1.22** **Plus HS+B.L1U1.9**		**Essential HS.L1U3.23**

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

Appendices

Appendix 1: Crosscutting Concepts

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

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

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

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

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

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

Appendix 2: Science and Engineering Practices

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

Distinguishing Science & Engineering Practices

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

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

	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.	process, with a critical stage being the selection of the most promising solution among a field of competing ideas. Engineers use systematic methods to compare alternatives, formulate evidence, based on test data, make arguments from evidence to defend their conclusions, evaluate critically the ideas of others, and revise their designs to achieve the best solution to the problem at hand.
Obtain, Evaluate, and Communicate Information	Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. Scientists need to express their ideas, orally and in writing, using tables, diagrams, graphs, drawings, equations, or models and by engaging in discussions with peers. Scientists need to be able to derive meaning from texts (such as papers, the internet, symposia, and lectures) to evaluate the scientific validity of the information and to integrate that information with existing theories or explanations. Scientists routinely use technologies to extend the possibilities for collaboration and communication.	Engineers cannot produce new or improved technologies if the advantages of their designs are not communicated clearly and persuasively. Engineers need to express their ideas, orally and in writing, using tables, graphs, drawings, or models and by engaging in discussions with peers. Engineers need to be able to derive meaning from colleagues' texts, evaluate the information, and apply it usefully. Engineers routinely use technologies to extend the possibilities for collaboration and communication.

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

Appendix 3: Core Ideas

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

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

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

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

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

Appendix 4: Equity & Diversity in Science

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

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

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

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

Appendix 5: Interdisciplinary Connections

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

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

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

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

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

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

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

Appendix 6: Connections to English Language Arts and Math

Kindergarten - 2nd Grade

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

3rd Grade - 5th Grade

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

6th Grade - 8th Grade

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

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