Arizona Science Standards
2018

Arizona Department of Education
High Academic Standards for Students

Introduction

Students are naturally curious about the world and their place in it. Sustaining this curiosity and giving it a scientific foundation must be a high priority in Arizona schools. Scientific thinking enables Arizona students to strengthen skills that people use every day: solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing lifelong learning. A fundamental goal of science education is to help students determine how the world works and make sense of phenomena in the natural world. Phenomena are 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 thirteen core ideas and develop learning progressions to coherently and logically build scientific literacy from kindergarten through high school.
- Connect **core ideas**, **crosscutting concepts**, and **science and engineering practices**, to make sense of the natural world and understand how science and engineering are practiced and experienced.
- Focus on fewer, broader standards that allow for greater depth, more connections, deeper understanding, and more applications of content.

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

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

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

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

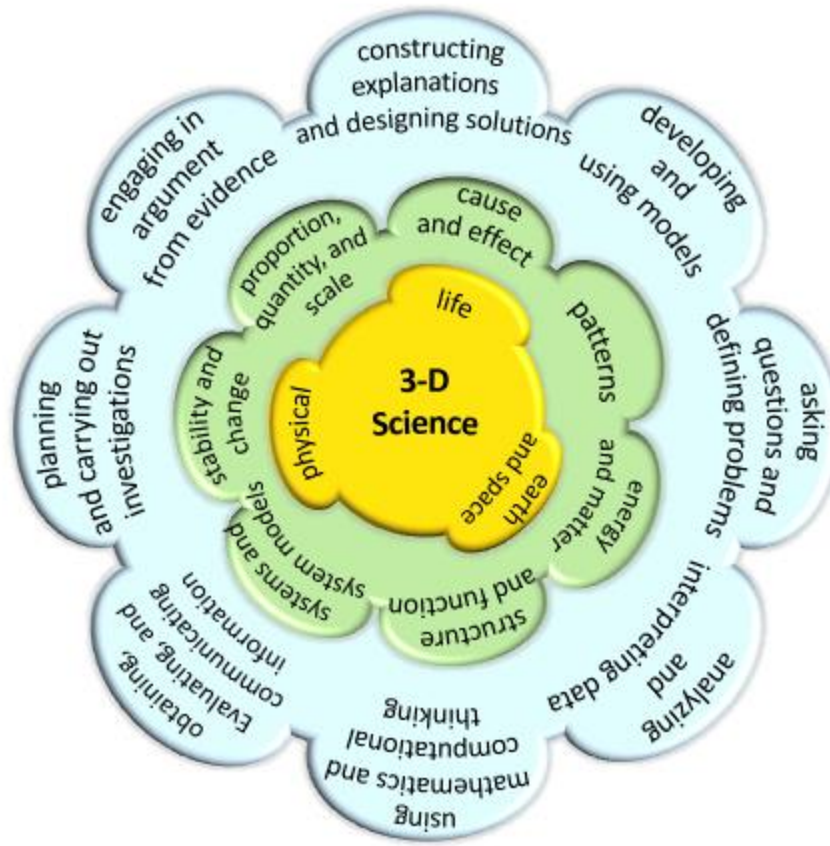


Figure 1: Three Dimensions of Science Instruction

Science and Engineering Practices

For decades teachers have utilized the scientific method as a methodology to engage in scientific inquiry. 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.

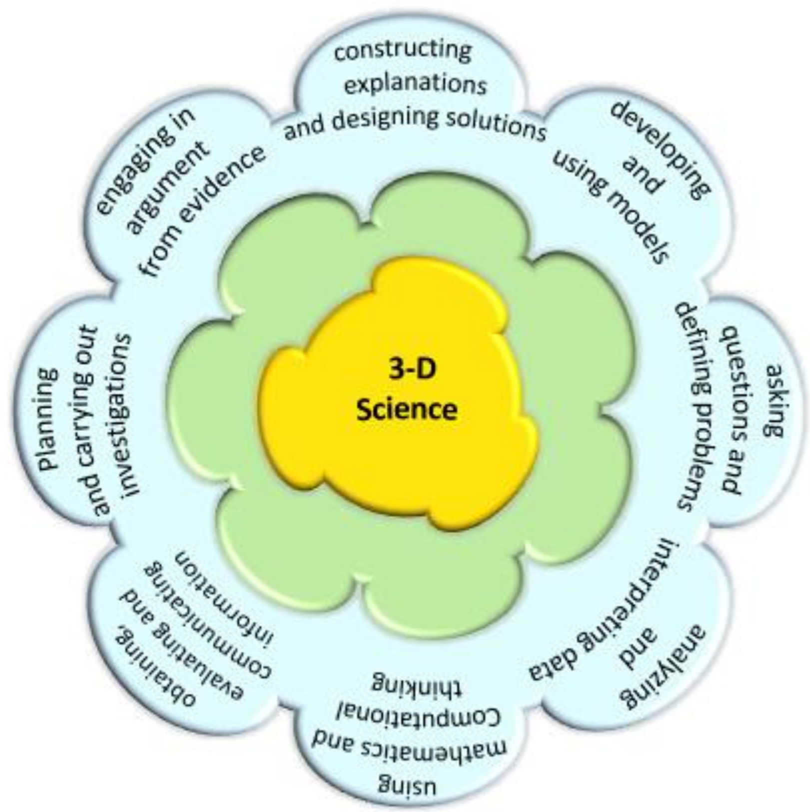


Figure 2: Science and Engineering Practices

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.

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

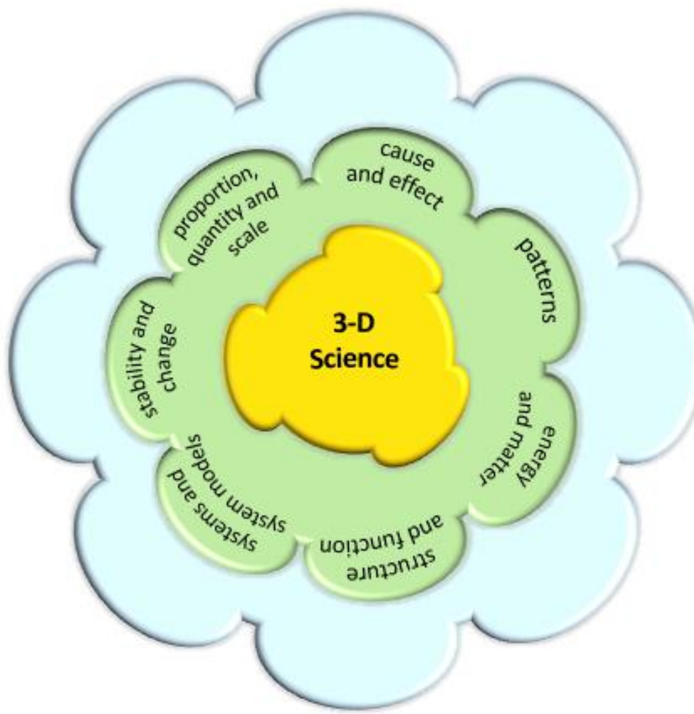


Figure 3: Crosscutting Concepts

Core Ideas

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

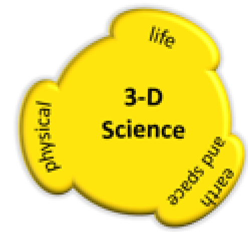


Figure 3: Core Ideas

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

Time Allotment

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

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

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

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

Safety Expectations

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

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

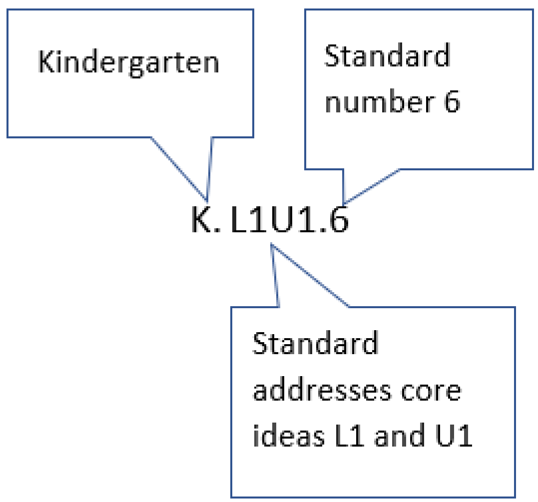
Chemical Storage Expectations

What You Can Do

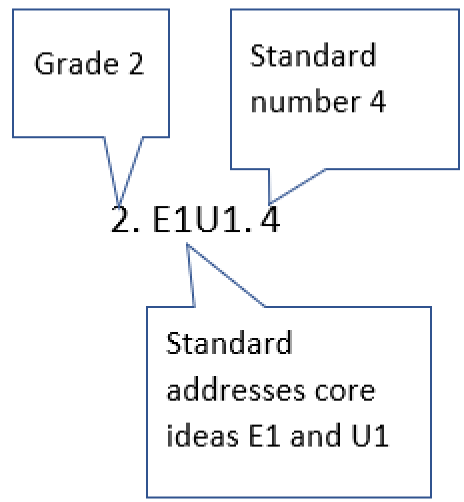
- Put in place an experienced leadership team to oversee chemical management, storage, and handling activities.
- Implement pollution prevention and green chemistry (safer alternatives) principles to minimize the use of hazardous chemicals at schools.
- Establish an environmentally preferable purchasing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

Coding of the K-8 Science Standards

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



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



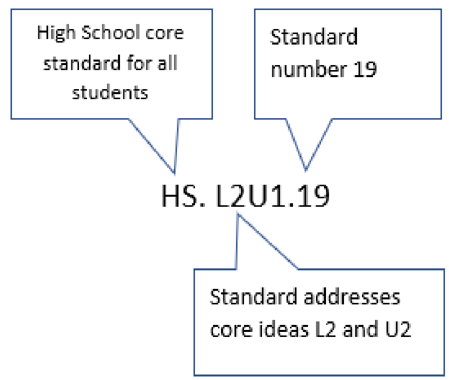
2.E1U1.4 Observe and investigate how wind and water change the shape of the land resulting in a variety of landforms.

Coding of the High School Science Standards

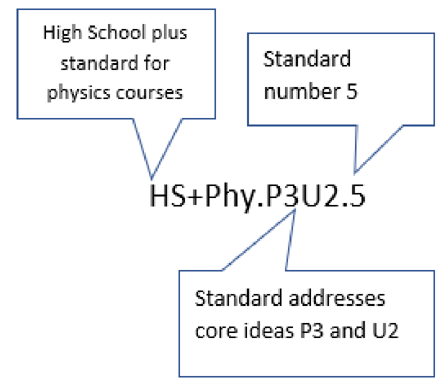
In Arizona, students are required to take 3 credits of high school science aligned to standards in physical, earth and space, and life sciences to meet graduation requirements, but there is no mandatory course sequence across the state. Because of this, the high school standards are written at two levels: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

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

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



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



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

Navigating the Standards Document

Standards	Support Material
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.

Grades K-2 Science Standards

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

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

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

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

Kindergarten: Focus on Patterns; Structure and Function

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Physical Science Standards	Learning Progressions, Key Terms, and Crosscutting Concepts
1.P2U1.1	
Plan and carry out investigations demonstrating the effect of placing objects made with different materials in the path of a beam of light and **predict** how objects with similar properties will affect the beam of light.	Some materials allow **light** to pass through them, others allow only some light through, and others block all the light and create a dark **shadow** on any surface beyond them (i.e., on the other side from the light source), where the light cannot reach. **Mirrors** and **prisms** can be used to redirect a light beam. [4] (p. 134-135) Light and sound are **wavelike** phenomena. **Sound** can make **matter vibrate**, and vibrating matter can make sound. [4] (p. 132) Crosscutting Concepts: **cause and effect;** systems and system models; energy and matter; **stability and change** [4]
1.P2U1.2	
Use models to provide evidence that vibrating matter creates sound and sound can make matter vibrate.	
1.P3U1.3	
Plan and carry out investigations which demonstrate how equal forces can balance objects and how unequal forces can push, pull, or twist objects, making them change their speed, direction, or shape.	**Forces** can **push**, **pull** or **twist** objects, making them change their **motion** or **shape**. Forces act in particular directions. **Equal forces** acting in opposite directions in the same line cancel each other and are described as being in **balance**. The movement of objects is changed if the forces acting on them are not in balance. [2] (p. 22) Crosscutting Concepts: **cause and effect;** systems and system models; energy and matter; **stability and change** [4]
1.P4U2.4	
Design and evaluate ways to increase or reduce heat from friction between two objects.	When two objects rub against each other, this interaction is called **friction.** Friction between two surfaces can warm both of them (e.g., rubbing hands together). There are ways to reduce the friction between two objects.[4] (p. 129) Designs can be conveyed through **sketches**, **drawings**, or **physical models.**[4] (p. 207)Because there is always more than one possible solution to a problem, it is useful to **compare** designs, **test** them, and **discuss** their **strengths** and **weaknesses.**[4] (p. 209) Crosscutting Concepts: **cause and effect;** systems and system models; energy and matter; **stability and change**; [4]

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

Earth and Space Standards	Learning Progressions, Key Terms, and Crosscutting Concepts
1.E1U1.5	
Obtain, evaluate, and communicate information about the properties of Earth materials and **investigate** how humans use natural resources in everyday life.	Wind and water can change the shape of the land. The resulting **landforms**, together with the materials on the land, provide homes for **living things.** [4 (p. 180)] Humans use **natural resources** for everything they do: for example, they use **soil** and **water** to grow **food**, **wood** to burn to provide **heat** or to build **shelters**, and materials such as **iron** or **copper (minerals)** extracted from Earth to make cooking pans.[4 (p. 192)] Crosscutting Concepts: **cause and effect;** systems and system models; energy and matter; **stability and change**[4]

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

Life Science Standards	Learning Progressions, Key Terms, and Crosscutting Concepts
1.L1U1.6	
Observe, **describe, and predict** life cycles of animals and plants.	**Plants** and **animals** have predictable **characteristics** at different **stages of development**. Plants and animals **grow** and change. Adult plants and animals can have **young.**[4(p. 146)] Crosscutting Concepts: **cause and effect;** structure and function; **stability and change**[4]
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
1.L2U1.8	

Construct an explanation describing how organisms obtain resources from the environment including materials that are used again by other organisms.	needs for water, minerals, and sunlight [4(. 151)] Animals need food that they can break down, which comes either directly by eating plants (herbivores) or by eating animals (carnivores) which have eaten plants or other animals. [2 (p. 27)] Designs can be conveyed through **sketches**, **drawings**, or **physical models.**[4 (p. 207)] Because there is always more than one possible solution to a problem, it is useful to **compare** designs, **test** them, and **discuss** their **strengths** and **weaknesses.**[4 (p. 209)] Crosscutting Concepts: **cause and effect;** systems and system models; energy and matter; structure and function; **stability and change**[4]
1.L3U1.9	
Obtain, evaluate, and communicate information to **support an evidence-based explanation** that plants and animals produce offspring of the same kind, but offspring are generally not identical to each other or their parents.	**Living** things produce **offspring** of the same kind, but offspring are not **identical** with each other or with their **parents**. Plants and animals, including humans, resemble their parents in many features because information is passed from one **generation** to the next.[2 (p. 22)] Organisms have **characteristics** that can be similar or different. Young animals are very much, but not exactly, like their parents and also resemble other animals of the same kind. Plants also are very much, but not exactly, like their parents and resemble other plants of the same kind.[4 (p. 158)] Crosscutting Concepts: **cause and effect;** structure and function; **stability and change** [4]
1.L4U1.10	
Develop a model to describe how animals and plants are classified into groups and subgroups according to their similarities. **1.L4U3.11** **Ask questions** and explain how factors can cause species to go extinct.	There are many different kinds of **plants** and **animals** in the world today and many kinds that once lived but are now **extinct**. We know about these from **fossils**. Animals and plants are **classified** into groups and subgroups according to their **similarities.**[2 (p.29)] Some kinds of plants and animals that once lived on Earth (e.g., dinosaurs) are no longer found anywhere, although others now living (e.g., lizards) resemble them in some ways.[4 (p. 162)] Crosscutting Concepts: **cause and effect;** systems and system models; energy and matter; structure and function; **stability and change**[4]

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

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

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

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

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

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

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

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

2.E1U3.7	
Construct an argument from evidence regarding positive and negative changes in water and land systems that impact humans and the environment.	Plants and animals (including humans) depend on the **land**, **water**, and **air** to live and grow. They in turn can change their **environment** (e.g., the shape of land, the flow of water).[4] (p. 190) Crosscutting Concepts: cause and effect; scale, proportion, and quantity; **systems and system models;** structure and function; stability and change[4]
2.E2U1.8	
Observe and explain the Sun's position at different times during a twenty-four-hour period and changes in the apparent shape of the Moon from one night to another.	There are patterns in the position of the **Sun** seen at different times of the **day** and in the shape of the **Moon** from one **night** to another.[2] (p. 25) Crosscutting Concepts: patterns; cause and effect; **systems and system models;** stability and change[4]

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

Life Science Standards	Learning Progressions, Key Terms, and Crosscutting Concepts
2.L2U1.9	
Obtain, analyze, and communicate evidence that organisms need a source of energy, air, water, and certain temperature conditions to survive.	All living things need food as their source of **energy** as well as air, water, and certain temperature conditions. Plants containing chlorophyll can use **sunlight** to make the food they need and can store food that they do not immediately use. Animals need food that they can break down, which comes either directly by eating plants (herbivores) or by eating animals (carnivores) which have eaten plants or other animals. Animals are ultimately dependent on plants for their survival. The relationships among organisms can be represented as **food chains** and **food webs.**[2] (p. 27) All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow.[4] (p. 147) Crosscutting Concepts: cause and effect; **systems and system models; energy and matter;** structure and function; stability and change[4]
2.L2U1.10	
Develop a model representing how life on Earth depends on energy from the Sun and energy from other organisms.	

Distribution of K-2 Standards

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

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 thirteen big ideas for knowing science and using science are adapted from *Working with Big Ideas of Science Education*[2] and represent student understanding of each core idea at the end of high school.

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

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

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

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

Appendix 4: Equity & Diversity in Science

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

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

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

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

Appendix 5: Interdisciplinary Connections

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

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

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

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

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

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

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

Appendix 6: Connections to English Language Arts and Math

Kindergarten - 2nd Grade

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

3rd Grade - 5th Grade

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

6th Grade - 8th Grade

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

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