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

By the end of eighth grade, students will describe how stability and change and the process of cause and effect influence changes in the natural world. Students will apply energy principles to chemical reactions, explore changes within Earth and understand how genetic information is passed down to produce variation among the populations. Student investigations focus on collecting and making sense of observational data and measurements using the [science and engineering practices](#_4ddeoix): ask questions and define problems, develop and use models, plan and carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations and design solutions, engage in argument from evidence, and obtain, evaluate, and communicate information. While individual lessons may include connections to any of the crosscutting concepts, the standards in eighth-grade focus on helping students understand phenomena through [cause and effect](#_4ddeoix), [energy and matter,](#_4ddeoix) and [stability and change](#_4ddeoix).

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| **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**](#_14hx32g) | | |

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

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| **Physical Science Standards** | **Crosscutting Concepts and Background Information for Educators** |
| **8.P1U1.1** | **Crosscutting Concepts:**  Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4](file:///C:\Users\rgarell\Downloads\Draft%20for%20Document%20Changes%20%20(1).docx#_14hx32g)  **Background Information:**  All materials, anywhere in the universe, living and non-living, are made of a very large numbers of basic ‘building blocks’ called **atoms**, of which there are about 100 different kinds. **Substances** made of only one kind of atom are called **elements**. Atoms of different elements can combine together to form a very large number of **compounds**. A **chemical reaction** involves a rearrangement of the atoms in the reacting substances to form new substances, while the total amount of matter remains the same. The properties of different materials can be explained in terms of the behavior of the atoms and groups of atoms of which they are made. [2](#_14hx32g) (p. 20) Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others store energy. [4](#_14hx32g) (p. 111) |
| [**Develop and use a model**](https://www.nap.edu/read/13165/chapter/7#56) to demonstrate that atoms and molecules can be combined or rearranged in chemical reactions to form new compounds with the total number of each type of atom conserved. |
| **8.P1U1.2** |
| [**Obtain and evaluate information**](https://www.nap.edu/read/13165/chapter/7#74) regarding how scientists identify substances based on unique physical and chemical properties. |
| **8.P4U1.3** | **Crosscutting Concepts and Background Information for Educators** |
| [**Construct an explanation**](https://www.nap.edu/read/13165/chapter/7#67) on how energy can be transferred from one energy store to another. | **Crosscutting Concepts:**  Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4](file:///C:\Users\rgarell\Downloads\Draft%20for%20Document%20Changes%20%20(1).docx#_14hx32g)  **Background Information:**  Objects can have stored energy (that is, the ability to make things change) either because of their chemical composition (as in fuels and batteries), their movement, their temperature, their position in a gravitational or other field, or because of compression or distortion of an elastic material.[2](#_14hx32g) (p. 23) **Energy** can be stored by lifting an object higher above the ground. When it is released and falls, this energy is stored in its **motion**. When an object is heated it has more energy than when it is cold. An object at a higher temperature heats the surroundings or cooler objects in contact with it until they are all at the same temperature. How quickly this happens depends on the kind of material which is heated and on the materials between them (the extent to which they are **thermal insulators** or **conductors**). The chemicals in the cells of a **battery** store energy which is released when the battery is connected so that an **electric current** flows, **transferring** **energy** to other components in the **circuit** and on to the environment. Energy can be transferred by **radiation**, as sound in air or light in air or a **vacuum**. Many processes and phenomena are described in terms of **energy exchanges**, from the growth of plants to the weather. The transfer of energy in making things happen almost always results in some energy being shared more widely, heating more **atoms** and **molecules** and spreading out by conduction or radiation. The process cannot be reversed and the energy of the random movement of particles cannot as easily be used. Thus, some energy is **dissipated**.[2](#_14hx32g) (p. 23) A simple wave has a repeating pattern with a specific **wavelength, frequency, and amplitude**. [4](#_14hx32g) (p. 132) |
| **8.P4U1.4** |
| [**Develop and use mathematical models**](file:///\\FILEI\INFO\School%20Effectiveness\ARIZONA%20ACADEMIC%20STANDARDS%20UNIT\Science%20Standards%202018%20Revision\FINAL%20Standards\Develop%20and%20use%20models)to explainwave characteristics and interactions. |
| **8.P4U2.5** |
| [**Develop a solution**](https://www.nap.edu/read/13165/chapter/12#205) to increase efficiency when transferring energy from one source to another. |

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

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| **Earth and Space Standards** | **Crosscutting Concepts and Background Information for Educators** |
| **8.E1U1.6** | **Crosscutting Concepts:**  Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4](file:///C:\Users\rgarell\Downloads\Draft%20for%20Document%20Changes%20%20(1).docx#_14hx32g)  **Background Information:**  **Plate tectonics** is the unifying theory that explains the past and current movements of the rocks at Earth’s surface and provides a framework for understanding its geological history. Plate movements are responsible for most **continental** and **ocean floor features** and for the distribution of most **rocks** and **minerals** within Earth’s **crust**. Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth’s plates have moved great distances, collided, and spread apart. [4](#_14hx32g) (p. 183) Some **natural hazards** are preceded by geological activities that allow for **reliable predictions**; others occur suddenly, with no notice, and are not yet predictable. By tracking the upward movement of magma, for example, volcanic eruptions can often be predicted with enough advance warning to allow neighboring regions to be evacuated. Earthquakes, in contrast, occur suddenly; the specific time, day, or year cannot be predicted. However, the history of earthquakes in a region and the mapping of fault lines can help forecast the likelihood of future events. Finally, satellite monitoring of weather patterns, along with measurements from land, sea, and air, usually can identify developing severe weather and lead to its reliable forecast. [4](#_14hx32g) (p. 193) **Evolution** is shaped by Earth’s varying geological conditions. Sudden changes in conditions (e.g., **meteor impacts, major volcanic eruptions**) have caused **mass extinctions**, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. The evolution and proliferation of living things over geological time have in turn changed the rates of **weathering** and **erosion** of land surfaces, altered the composition of Earth’s soils and **atmosphere**, and affected the distribution of water in the **hydrosphere**. [4](#_14hx32g) (p. 190) Human activities have significantly altered the **biosphere**, sometimes damaging or destroying natural **habitats** and causing **extinction** of many other species. But changes to Earth’s environment can have different impacts (negative and positive) for different living things. Typically, as human populations and **per-capita consumption** of **natural resources** increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. |
| [**Analyze and interpret data**](https://www.nap.edu/read/13165/chapter/7#61)about the Earth’s geological column to [**communicate**](https://www.nap.edu/read/13165/chapter/7#74) relative ages of rock layers and fossils. |
| **8.E1U3.7** |
| [**Obtain, evaluate, and communicate**](https://www.nap.edu/read/13165/chapter/7#74) information about data and historical patterns to predict natural hazards and other geological events**.** |
| **8.E1U3.8** |
| [**Construct and support an argument**](https://www.nap.edu/read/13165/chapter/7#71) about how human consumption of limited resources impacts the biosphere. |

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

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| **Life Science Standards** | **Crosscutting Concepts and Background Information for Educators** |
| **8.L3U1.9** | **Crosscutting Concepts:**  Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4](file:///C:\Users\rgarell\Downloads\Draft%20for%20Document%20Changes%20%20(1).docx#_14hx32g)  **Background Information:**  **Genes** are located in the **chromosomes** of **cells**, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of a specific **protein**, which in turn affects the **traits** of the individual (e.g., human skin color results from the actions of proteins that control the production of the pigment melanin). Changes (**mutations**) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. **Sexual reproduction** provides for transmission of genetic information to offspring through **egg** and **sperm** **cells**. These cells, which contain only one chromosome of each parent’s chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent’s chromosome pair (forming a new chromosome pair). Variations of **inherited** **traits** between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited or (more rarely) from mutations. (Boundary: The stress here is on the impact of gene transmission in reproduction, not the mechanism.) [4](#_14hx32g) (pp. 158-159) In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two **alleles** of each gene, one acquired from each parent. These versions may be identical or may differ from each other. In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are **beneficial, others harmful, and some neutral to the organism**. [4](#_14hx32g) (p. 160) |
| [**Construct an explanation**](https://www.nap.edu/read/13165/chapter/7#67) of how genetic variations occur in offspring through the inheritance of traits or through mutations. |
| **8.L3U3.10** |
| [**Communicate**](https://www.nap.edu/read/13165/chapter/7#74)how advancements in technology have furthered the field of genetic research and use [**evidence to support an argument**](file:///\\FILEI\INFO\School%20Effectiveness\ARIZONA%20ACADEMIC%20STANDARDS%20UNIT\Science%20Standards%202018%20Revision\FINAL%20Standards\Engage%20in%20argument%20from%20evidence) about the positive and negative effects of genetic research on human lives. |

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| **8.L4U1.11** | **Crosscutting Concepts and Background Information for Educators** |
| [**Develop and use a model**](https://www.nap.edu/read/13165/chapter/7#56) to explain how natural selection may lead to increases and decreases of specific traits in populations over time. | **Crosscutting Concepts:**  Patterns; **Cause and Effect**; Scale, Proportion and Quantity; Systems and System Models; **Energy and Matter**; Structure and Function; **Stability and Change**[4](file:///C:\Users\rgarell\Downloads\Draft%20for%20Document%20Changes%20%20(1).docx#_14hx32g)  **Background Information:**  Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as **natural selection**. It leads to the predominance of certain traits in a population and the suppression of others. In **artificial selection**, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. [4](#_14hx32g) (p. 164) **Adaptation** by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to become separate species. [4](#_14hx32g) (p. 165) Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on Earth, from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). Changes in biodiversity can influence humans’ resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling. [4](#_14hx32g) (p. 167) |
| **8.L4U1.12** |
| [**Gather and communicate**](https://www.nap.edu/read/13165/chapter/7#74)[**evidence**](https://www.nap.edu/read/13165/chapter/7#71) on how the process of natural selection provides an explanation of how new species can evolve. |

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

# Appendices

## Appendix 1: Crosscutting Concepts

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

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

The crosscutting concepts and their progressions from *Chapter 4 Crosscutting concepts pages 83 - 102 in* *A Framework for K-12 Science Education*[4](#_3tm4grq)are summarized below.

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| **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](#_28reqzj) 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](#_14hx32g)are critical components of scientific literacy. They are not instructional strategies.

**Distinguishing Science & Engineering Practices**

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|  | **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 investigationsmay 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 investigationsproduce 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 isa systematic process for solving engineering problems and is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, feasibility, cost, safety, aesthetics, and compliance with legal requirements. There is usually no single best solution but rather a range of solutions. The optimal solution often depends on the criteria used for making evaluations. |
| **Engage in Argument from Evidence** | In science, reasoning and argument are essential for identifying the strengths and weaknesses of a line of thinking and for finding the best explanation for a phenomenon. Scientists must defend their explanations, formulate evidence, based on a solid foundation of data, examine their own understanding in light of the evidence and comments offered by others, and collaborate with peers in searching for the best explanation for the phenomenon being investigated. | In engineering, reasoning and argument are essential for finding the best possible solution to a problem. Engineers collaborate with their peers throughout the design process, with a critical stage being the selection of the most promising solution among a field of competing ideas. Engineers use systematic methods to compare alternatives, formulate evidence, based on test data, make arguments from evidence to defend their conclusions, evaluate critically the ideas of others, and revise their designs to achieve the best solution to the problem at hand. |
| **Obtain, Evaluate, and Communicate Information** | Sciencecannot 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 scientificvalidity 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. | Engineerscannot 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](#_14hx32g)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](#_3tm4grq)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](#_3tm4grq) and represent student understanding of each core idea at the end of high school.

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| 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 themhappen. Energy can be transferred from one body or group of bodies to another invarious ways. In these processes, some energy becomes less easy to use. Energy cannotbe created or destroyed. |

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

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

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| Core Ideas for Using Science |  |
| **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](#_14hx32g) (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](#_14hx32g) (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](#_14hx32g) (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](#_14hx32g) (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](#_14hx32g).

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](#_14hx32g). 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](#_14hx32g). Science teachers need to acquire effective strategies to include all students regardless of age, racial, ethnic, cultural, linguistic, socioeconomic, and gender backgrounds3.

Effective teaching strategies3 for attending to equity and diversity for

* **Economically disadvantaged students** include (1) connecting science education to students’ sense of “place” as physical, historical, and sociocultural dimensions in their community; (2) applying students’ “funds of knowledge” and cultural practices; and (3) using problem-based and project-based science learning centered on authentic questions and activities that matter to students.
* **Underrepresented racial and ethnic groups** include (1) culturally relevant pedagogy, (2) community involvement and social activism, (3) multiple representations and multimodal experiences, and (4) school support systems including role models and mentors of similar racial or ethnic backgrounds.
* **Indigenous students** include (1) learning and knowing that is land- and place-based, (2) centers (not erases or undermines) their ways of knowing, and (3) builds connections between Indigenous and western Science Technology Engineering and Mathematics (STEM), and (4) home culture connections8.
* **Students with disabilities** include (1) multiple means of representation, (2) multiple means of action and expression, (3) multiple means of engagement, (4) concrete experiences with realia, and (5) scaffolds in problem-based and project-based learning.
* **English language learners** include (1) literacy strategies for all students, (2) language support strategies with English language learners, (3) discourse strategies with English language learners, (4) home language support, (5) home culture connections, (6) concrete experiences with realia, and (7) scaffolds in problem-based and project-based learning.
* **Alternative education setting for dropout prevention** include (1) structured after-school opportunities, (2) family outreach, (3) life skills training, (4) safe learning environment, and (5) individualized academic support.
* **Girls’ achievement, confidence, and affinity with science** include (1) instructional strategies, (2) curricular decisions, and (3) classroom and school structure.
* **Gifted and talented students** include (1) different levels of challenge (including differentiation of content), (2) opportunities for self-direction, and (3) strategic grouping.

## 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.

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| [**English Language Arts**](http://www.azed.gov/standards-practices/k-12standards/english-language-arts-standards/) |
| 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. |

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| [**Mathematics**](http://www.azed.gov/standards-practices/k-12standards/mathematics-standards/) |
| 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. |

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| **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. |

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| **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. |

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| [**Social Studies**](http://www.azed.gov/standards-practices/k-12standards/standards-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

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|  | **Kindergarten** | **1st Grade** | **2nd Grade** |
| [Arizona English Language Arts](http://www.azed.gov/standards-practices/k-12standards/english-language-arts-standards/) | 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](http://www.azed.gov/standards-practices/k-12standards/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

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|  | **3rd Grade** | **4th Grade** | **5th Grade** |
| [Arizona English Language Arts](http://www.azed.gov/standards-practices/k-12standards/english-language-arts-standards/) | 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](http://www.azed.gov/standards-practices/k-12standards/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

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|  | **6th Grade** | **7th Grade** | **8th Grade** |
| [Arizona English Language Arts](http://www.azed.gov/standards-practices/k-12standards/english-language-arts-standards/) | 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](http://www.azed.gov/standards-practices/k-12standards/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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