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Executive Summary

Science Framework

FOR CALIFORNIA PUBLIC SCHOOLS
Kindergarten Through Grade Twelve

February 2018

What's in the *California Science Framework* for me?

- **Classroom teachers and paraprofessionals of all grades and disciplines** will find descriptions of grade-level science and engineering instruction and examples of engaging teaching and assessment practices for ensuring the progress of the diverse students they serve.
- **Site and district administrators** will find information about the vision of California Next Generation Science Standards (CA NGSS) instruction, recommended practices and systemic supports, and suggestions for creating the collaborative culture necessary to successfully implement the framework and serve students and communities well. They will also find criteria for evaluating instructional materials.
- **University faculty in teacher preparation programs** will find information regarding CA NGSS instruction for prospective teachers and in-service teachers. They will also find information about district systems that support teachers and the students they serve.
- **Parents and community members** will find grade-level expectations and examples of effective instruction.
- **Curriculum developers** will find expectations for instructional materials and models of appropriate instructional approaches and assessment practices.

The complete *Science Framework for California Public Schools* is available online at https://www.cde.ca.gov/ci/sc/cf.

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The *California Science Framework* at a Glance

The *Science Framework for California Public Schools: Kindergarten Through Grade Twelve* (framework) supports a three-dimensional vision of science education. In the California Next Generation Science Standards (CA NGSS), students need to do more than simply know about science; they need to *know* core science and engineering ideas, *do* science and engineering, and *think* like scientists and engineers.

The framework is a valuable resource for teachers, administrators, parents, and curriculum developers. The examples given in each chapter provide a vision of how science instruction and learning could look in a classroom, and teachers should use the examples as a starting point. The framework includes thematic and specific grade-level chapters.

Overview	
Chapter 1	• Overview (and how to read the standards)
Grade-Level Guidance	
Chapter 2	• Transitional Kindergarten (TK)
Chapter 3	• Kindergarten–Grade Two (K–2)
Chapter 4	• Grades Three–Five (3–5)
Chapters 5 and 6	• Middle Grades (MG)
Chapters 7 and 8	• High School (HS)
Topic-Specific Guidance	
Chapter 9	• Assessment of Student Learning
Chapter 10	• Access and Equity
Chapter 11	• Instructional Strategies for CA NGSS Teaching and Learning in the Twenty-First Century
Chapter 12	• Implementing High-Quality Science Instruction: Professional Learning, Leadership, and Supports
Chapter 13	• Instructional Resources to Support the Next Generation Science Standards for California Public Schools, Kindergarten Through Grade Twelve
Appendixes	
Appendix 1	• Progression of SEPs, DCIs, and CCCs in Kindergarten Through Grade Twelve
Appendix 2	• Connections to Environmental Principles and Concepts
Appendix 3	• Computer Science in Science
Appendix 4	• High School Three-Year Model: Every Science, Every Year
Appendix 5	• Recommended Literature for Science Classrooms

Key Acronyms in the *CA Science Framework*

CCC = Crosscutting Concept
DCI = Disciplinary Core Idea
EP&Cs = Environmental Principles and Concepts
IS = Instructional Segment
SEP = Science and Engineering Practices
PE = Performance Expectation

Framework Overview

The overview chapter of the framework describes each of the three dimensions in detail and describes how they fit together. When teachers integrate all three dimensions of the CA NGSS, their classrooms look different. A table within the overview shows a few examples of how the actions of both teachers and students change. The framework organizes these shifts into three key categories:

- *Phenomena-driven three-dimensional learning*. Students engage in scientific inquiry of phenomena using all three dimensions of the CA NGSS.
- *Coherent across the curriculum*. Learning builds upon itself from year to year and science integrates with other subject areas.
- *Relevant to local communities and student interests*. Content and skills build on students' existing experience to learn about and solve real-world problems.

Phenomena-Driven Three-Dimensional Learning

The framework defines *phenomena* as authentic events that students observe in everyday experience or through structured investigations. In the CA NGSS, phenomena-driven instruction and selecting appropriate phenomena are crucial to effective instruction. Vignettes and snapshots within the framework provide example phenomena, and this summary highlights phenomena from each grade level.

Examples of Phenomena

Grade	Phenomenon
Kindergarten	Classroom pets need food and water to survive.
First	A baby crayfish in the class aquarium has claws just like its mother.
Second	Some plants make seeds that stick to clothing.
Third	Three magnets connected together are stronger than one magnet.
Fourth	Turning a hand crank can generate electricity to make a bulb light up.
Fifth	Wax, chocolate, and ice all have different melting temperatures.

During science learning, students apply three different kinds of skills and understanding to their investigation of specific phenomena. The CA NGSS names these understandings the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs). Throughout the framework, color coding calls out how students use all three dimensions together to understand a phenomenon. To emphasize how learning integrates the dimensions, the NGSS logo shows the three dimensions as a Mobius strip (a surface that has only one continuous side). The table below describes each of the three dimensions.

Figure 1.1. The NGSS Logo Illustrates the Three Dimensions of Science.

Dimension 1: Science and Engineering Practices (SEPs)	Behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems	What scientists and engineers *do*
Dimension 2: Disciplinary Core Ideas (DCIs)	Key organizing concepts, problem solving tools, or underlying principles of a discipline	What scientists and engineers *know*
Dimension 3: Crosscutting Concepts (CCCs)	Underlying themes that have value in all disciplines of science	How scientists and engineers *think*

This table from the framework lists the components of three-dimensional science. The framework provides grade-level explanations and examples of each of these important components and how they can be used together to understand, explain, and design solutions for phenomena that students observe. The three dimensions help students begin to do, know, and think like scientists.

Table 1.1. The Three Dimensions of the CA NGSS

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
SEP-1. Asking Questions and Defining Problems SEP-2. Developing and Using Models SEP-3. Planning and Carrying Out Investigations SEP-4. Analyzing and Interpreting Data SEP-5. Using Mathematics and Computational Thinking SEP-6. Constructing Explanations (for science) and Designing Solutions (for engineering) SEP-7. Engaging in Argument from Evidence SEP-8. Obtaining, Evaluating, and Communicating Information	**Physical Science** PS1: Matter and Its Interactions PS2: Motion and Stability: Forces and Interactions PS3: Energy PS4: Waves and Their Applications in Technologies for Information Transfer **Life Science** LS1: From Molecules to Organisms: Structures and Processes LS2: Ecosystems: Interactions, Energy, and Dynamics LS3: Heredity: Inheritance and Variation of Traits LS4: Biological Evolution: Unity and Diversity **Earth and Space Science** ESS1: Earth's Place in the Universe ESS2: Earth's Systems ESS3: Earth and Human Activity Engineering, Technology, and Applications of Science ETS1: Engineering Design ETS2: Links Among Engineering, Technology, Science, and Society	CCC-1. Patterns CCC-2. Cause and Effect: Mechanism and Explanation CCC-3. Scale, Proportion, and Quantity CCC-4. Systems and System Models CCC-5. Energy and Matter: Flows, Cycles, and Conservation CCC-6. Structure and Function CCC-7. Stability and Change

Coherent Instruction Across the Curriculum

Students at each grade level build on and connect their new learning to what they have learned previously. Within science, student learning spirals upward as they revisit core ideas multiple times, adding additional layers of complexity and refining conceptual models. Students can investigate the same scientific question in high school that they explored in kindergarten, but with much greater sophistication. Appendix 1 in the framework includes tables that describe the progression of what students should understand and know at the end of each grade span for every SEP, DCI, and CCC.

In addition to these vertical connections, students must also connect ideas from one discipline to another horizontally. The SEPs reflect the full range of the scientific enterprise where students must listen, speak, read, write, use mathematics, and think critically and creatively. The framework includes boxes with example opportunities for connections to mathematics, English language arts/literacy (ELA), and English language development (ELD) in the grade-level chapters to support an integrated curriculum.

Learning Relevant to Student Experience and Community Needs

Students are more likely to meet the goals of the CA NGSS when science instruction centers on the interests and needs of students and communities, as well as the contributions of scientists and engineers who reflect California's diverse population. The "Access and Equity" chapter specifically addresses strategies for teaching students with diverse backgrounds.

The CA NGSS were designed to help students see connections between humans and the natural world and to address environmental challenges today and in the future. California has identified several critical understandings, called the Environmental Principles and Concepts (EP&Cs). Many of the vignettes and snapshots within the framework engage students in environmental learning, and each instructional segment articulates relevant connections to the EP&Cs. These experiences begin locally in elementary grades (e.g., reducing runoff of rainwater from the schoolyard in grade five), expand statewide in the middle grades (e.g., calculating the water needs of California's agriculture and using them to make informed dietary choices), and reach globally in high school (e.g., predicting and mitigating the impact of climate change on unique California species such as the American pika).

Human society has progressed beyond the time when simply learning about the natural world was a sufficient goal for science education. Today, the scale of our natural resource needs and impacts requires that our citizens be active problem solvers. To accomplish this goal, the CA NGSS require a major instructional shift to include engineering and technology in the standards and instruction. The framework's grade-span chapters have boxes suggesting specific engineering connections. Student design challenges include earthquake-safe structures (grade four), chemical engineering of pancakes (grade five), a wind farm (grade six), a landslide early warning system (grade seven), and a solar oven (high school).

Beyond the Three Dimensions

While the three dimensions are a major part of the CA NGSS, the standards are based on principles that go beyond these three dimensions. The framework overview has sections that discuss the environmental principles and concepts, engineering design, the nature of science, language demands in the CA NGSS, mathematical and computational thinking, twenty-first-century learning skills, and integrating science with California's other content standards.

Grade-Level Guidance

The framework includes grade-level examples organized into chapters devoted to grade spans (transitional kindergarten, kindergarten through grade two, grades three through five, middle grades, high school). Each chapter has an introduction that places learning in that grade span within the developmental sequence of the CA NGSS and addresses issues and decisions schools need to make to implement a coherent curriculum throughout the grade span. Each grade-level section includes the following:

- Example instructional segments (IS) centered on questions about observations of a specific phenomenon
- Color coding calling out each of the SEPs, DCIs, and CCCs
- One vignette showing an extended learning sequence
- Snapshots highlighting one specific instructional shift
- Engineering Connections providing example design challenges
- Opportunities for mathematics and ELA/ELD connections (all grades) and sample integration of science and ELD standards in the classroom (for kindergarten through grade six only)

The example instructional segments show one possible way to bundle the standards so that learning follows a conceptual flow. The instructional segments are not uniform curricular units—different phenomena require different amounts of investigation to explore and understand, so each instructional segment takes a different fraction of the school year. Each grade-span chapter ends with an additional vignette that highlights a deliberate approach to integrate the CA CCSS for ELA/Literacy, the CA ELD Standards, and the CA NGSS in a way that enhances all three of these areas. This vignette covers the same lesson sequence as one of the grade-level vignettes through this different lens.

Transitional Kindergarten and Kindergarten to Grade Two

Young children are natural explorers and builders—they are innately curious about the world, motivated to learn about it, and eager to find ways to make it better. Early childhood educators are charged with helping direct that energy toward activities that cultivate curiosity, patience, perseverance, and a love of learning. The CA NGSS were designed so that students progressively build skills and understanding in a developmentally appropriate sequence. Young students learn best when they begin their science learning by engaging with phenomena through exploration and play.

This table from the framework emphasizes developmental appropriateness by adapting the science and engineering practices to the K–2 level. Probably the most important skills for students in this grade span are to notice patterns and ask questions about them.

Table 3.1. Age-Appropriate Science and Engineering Practices

As stated in standards	Adapted for K–2
Asking Questions (Science)/Defining Problems (Engineering)	Wondering (science)/Deciding the "rules" (engineering)
Developing and Using Models	Drawing diagrams, building models, and coming up with ways to think about how things work
Planning and Carrying Out Investigations	Doing "exploriments"
Analyzing and Interpreting Data	Comparing and looking for patterns
Using Mathematical and Computational Thinking	Counting and measuring
Constructing Explanations (Science)/ Designing Solutions (Engineering)	Describing what happened (science)/Tinkering (engineering)
Engaging in Argument from Evidence	"I think ____ because I see or know ____."
Obtaining, Evaluating, and Communicating Information	Writing, drawing, or talking (acting out) about what we know, read, and understand about new discoveries (things) (ELA connections)

Transitional Kindergarten

Highlighted Phenomena from Transitional Kindergarten

- Changing the number of blocks below a sloped ramp makes a toy car roll farther.
- A rain stick makes noises when shaken that give clues about what is inside.
- Upon close inspection, a caterpillar has a pattern of yellow and white stripes.
- Flour and water get sticky when mixed together.
- It was foggy when school started but sunny at the end of the day.

Science is driven by curiosity about the natural world, so a primary objective is to cultivate curiosity at the transitional kindergarten (TK) level. Unlike kindergarten, the CA NGSS do not define grade-specific content standards for TK. The TK chapter discusses learning progressions that bridge from the California Preschool Learning Foundations for science to the CA NGSS for kindergarten.

In TK, teachers are essential for setting up the environment, scaffolding the exploration, and guiding language development around the phenomena. Play not only allows for socio-emotional development, but it is also deeply cognitive and designed to help children learn. Outdoor play provides children opportunities to practice directing their own exploration and investigation, while dramatic or pretend play is a method of processing and communicating information.

CA NGSS learning begins with experiencing an event or making an observation about the world (referred to as a phenomenon). Tables within the TK chapter of the framework are filled with example student actions and experiences that lead to further exploration. Some examples are problem-solving tasks that lay the groundwork for engineering design in later grades, while many others emphasize outdoor experiences where students cultivate a connection with the world around them as a foundation for California's EP&Cs. One table focuses on connections between the scientific-inquiry strand of the preschool foundations and the SEPs from the kindergarten standards. The other main table in the chapter shows example connections between the preschool foundations of scientific knowledge and the disciplinary core ideas in physical science, life science, and Earth and space sciences. Each foundation topic also includes a suggested link to an appropriate crosscutting concept.

Kindergarten

Highlighted Phenomena from Kindergarten

- A squirrel on the schoolyard digs in the ground to hide a nut.
- Students need a jacket at recess some days but not on other days.
- Rabbits spend most of their time in the shade on sunny days.
- Flappers in a cardboard pinball machine make the marble bounce off at different speeds and directions.

Kindergarten introduces several phenomena that students will revisit in later grades. At this level, students focus on observing what happens and asking questions that build their curiosity. As their language develops, they describe what they see and notice patterns that recur. In later grades, they will use these patterns as evidence to explain how or why events occur.

In IS1 (Plant and Animal Needs), students take a walk around their schoolyard and a virtual field trip down a river to observe different living things. They sort these living things into two categories (which might include plants versus animals) and describe the similarities and differences. In a snapshot, students notice that certain plants and animals live in certain environments. These experiences help students develop a mental model of what plants and animals need to survive.

In IS2 (Animals and Plants Can Change Their Environment), students make detailed observations of how plants and animals change their environment to meet their needs. A snapshot highlights that humans also modify our environment when we consume resources to produce the objects we use every day.

In IS3 (Weather Patterns), students record weather patterns and consider how those patterns affect them and other living things. In a vignette, students plan for a new class pet, a rabbit. They read about how native California jackrabbits stay cool in the wild, and then they engineer a shade structure to protect their pet (including designing, building, and testing the structure using a rabbit made of ultraviolet-sensitive beads).

In IS4 (Pushes and Pulls), they focus on physical interactions beginning with seemingly unstructured play with marbles and ramps. In reality, the students are both playing and engaging with real-world phenomena using the three dimensions of the CA NGSS. The framework describes opportunities for teachers to invite students to make predictions, test them, and explain the observed outcomes. Eventually, students make pictorial models in which they draw how pushes and pulls affect the motion of objects. A snapshot focuses on developing language using a strategy called "classroom talk." An engineering connection challenges students to build a structure out of blocks and then design a solution that protects their structure from a heavy ball rolling towards it.

Grade One

Highlighted Phenomena from Grade One

- Some plants in the school garden climb like beans, others grow underground like radishes, and others are low on the ground like lettuce.
- When two pieces of sandpaper rub together, they make a sound.
- During a game of shadow tag, everyone's shadow points the same direction.
- The Moon is sometimes visible during the day.

The grade one section in the framework builds on what students learned in kindergarten about how plants and animals meet their needs. The CCC of patterns is a major theme throughout the year.

The anchoring phenomena in IS1 (Plant Shapes) come from a schoolyard nature hunt. Students ask a variety of questions about objects they collect: Why is some bark smooth and other bark rough? Why do plants have leaves with different shapes? What's inside an acorn? Neither the students nor the teachers will answer these questions in grade one, but the framework shows teachers how they can help students refine their questions to focus on how specific plant structures serve functions that help the plant meet its needs. In an engineering connection, students design a structure inspired by structures in nature that will solve a problem their school faces. For example, after deciding that they need a better place to put their jackets, they design a coat rack that has enough hooks for all their jackets. Their design mimics the shape of a tree with branches and roots.

In IS2 (Animal Sounds), students learn about behaviors that animals use to meet their needs. They focus first on how animals form families. In a snapshot, students use picture cards to match animal offspring to their parents, developing their language skills as they use sentence frames and graphic organizers to describe how the parent and the children are similar and how they are different. In an engineering challenge that helps students understand social interactions in animals and the physical nature of sound, they create a musical device that mimics the communication of a baby animal and its parent.

Students notice consistent patterns in their shadow's shape and size by beginning IS3 (Shadows and Light) with a game of shadow tag in which their shadow always points the same direction on the schoolyard. Students then investigate how light interacts with different materials. Why does light pass through a glass window but cast a shadow when a person blocks it?

By returning to the schoolyard at different times to play shadow tag, students notice that their shadow points in different directions at different times of day. In IS4 (Patterns of Motion of Objects in the Sky), they use this anchoring phenomenon as the basis for an in-depth vignette to track their shadows. The framework places this experience in its developmental context—students are not yet expected to develop models of Earth rotating but instead document the pattern and use it to make predictions.

Grade Two

Highlighted Phenomena from Grade Two

- On a map of their town, students notice that some areas are city, some are farm fields, and some are natural environments.
- Water soaks into the sandbox quickly but makes a puddle on the blacktop.
- When you pour a lot of water in the sandbox, it starts to carve a river.
- Different numbers of organisms and types of organisms live in different locations on the schoolyard.

The theme of grade two in framework is landforms—students look out at the landscape around them and ask questions such as, How did it get to look the way it does? How does the landscape affect people and other living organisms?

Setting the stage for more advanced study of landforms in future grades, students begin by developing tools to describe and represent landscapes. Students start IS1 (Landscape Shapes) by digging in a sandbox to create a landscape and then represent it with maps. Students describe their landscape using words and simple geometric shapes.

Instructional segment 2 (Landscape Materials) begins with students observing and describing everyday materials on their schoolyard. The chapter shows teachers how to help students use these verbal descriptions to categorize a range of material by their properties. In an engineering connection, students play the role of agricultural engineers, combining materials to create a soil that retains moisture to help plants grow in their school garden. Students link other schoolyard materials to objects with specific uses. How do the properties of the material make it well suited to be used in that object? In another engineering connection, students dismantle small appliances to see what parts they have and what materials are used.

In IS3 (Landscape Changes), students investigate erosion in a hands-on stream table. Students describe how some landscape changes are rapid while others occur slowly. In an engineering challenge, they use their knowledge of landscape materials to design a solution that minimizes erosion in the stream table.

In IS4 (Biodiversity in Landscapes), students revisit the idea from kindergarten that different plants and animals live in different habitats. In a vignette, students map biodiversity in their schoolyard, count different organisms they observe, and represent their data using graphs. They also document how landscapes are changing (both the physical landforms and the living things) and develop solutions that can improve the habitat.

Grades Three to Five

The framework aligns with the developmental progress of students in grades three to five. While students notice patterns in the primary grades, they are now responsible for collecting more detailed observations and measurements. They analyze and interpret patterns in their data as evidence that one event causes another, but in many cases they do not fully explain how or why things happen. Many questions remain unanswered until later grades when students put together the pieces that they build in elementary school. The framework clarifies what elementary teachers are and are not expected to accomplish by articulating how students will build upon their elementary foundation in later grades.

The framework also provides examples of problems and phenomena from larger and larger scales as student capabilities expand. In grade three, they continue to focus in on their schoolyard experiences (forces experienced on a soccer ball, hazards from extreme weather events on campus). In grade four, students expand to concrete events in the community and state of California (car crashes, the sculpting of California's mountains and valleys, earthquake engineering, and our need for solar and wind power). In grade five, they push out to the sub-microscopic scale (what is matter made of?) and the inconceivably large (distant stars and galaxies).

Grade Three

Highlighted Phenomena from Grade Three

- A ball sometimes rises off the ground when kicked but other times rolls along the ground.
- As students observe a caterpillar in their classroom, they learn that the largest moths in the world never eat once they turn into a moth (they get all their food when they are caterpillars).
- Lupine species that grow in the California foothills look different from lupine species that live in the desert.
- The temperature suddenly jumped 10°F in one day.

In grade three, students revisit many activities from earlier grades with a focus on measurement (weight, length, distance) and analysis of data.

In IS1 (Playground Forces), students investigate forces they experience during regular play on the schoolyard. In a snapshot, they create diagrams that model the relationship between the force of their kick and the motion of the ball. The Engineering Connection in IS1 calls for students to use magnets to invent a more exciting swing for their playground.

Students can observe lifecycles at very early ages (e.g., seeds or butterflies), but the framework describes how to go beyond simply describing the sequences and patterns. In IS2 (Life Cycles for Survival), students address the question, How do animals' lifecycles help them survive? Students build on their prior learning about the needs of organisms and tie these lifecycles to reproduction. In a snapshot, students hatch caterpillar eggs so that they can measure the variation in the growth rates of caterpillars and interpret the data in terms of which caterpillars are more likely to survive.

Students measure growth rates again in IS3 (Surviving in Different Environments) as they investigate how different environmental conditions affect classroom or garden plants. In a snapshot, students take a walking trip around their neighborhood and compare the habitat of their schoolyard, the neighborhood streets, and a local park. In an engineering connection in IS2, students design solutions to a local environmental problem, such as the possibility of harmful pesticides polluting a local river during a levy breach.

While students monitored weather conditions in kindergarten, the vignette in IS4 (Weather Impacts) includes precise measurements. Students analyze the data to discover seasonal patterns and extreme deviations from those patterns that might be weather hazards. Students then propose possible solutions to their school site council that could reduce the risk of weather hazards on their schoolyard, such as anti-slip strips on a ramp or planting trees near the blacktop.

Grade Four

Highlighted Phenomena from Grade Four

- When a big toy car collides with a small toy car, the small car moves farther than when two small cars collide.
- In a plastic tub that models a river, water erodes more material when the slope is steeper.
- The amplitude of shaking varies during an earthquake.
- Some animals have eyes on the sides of their heads, but others have eyes that face forward.

The framework provides example phenomena for science that connect to the focus on California in fourth grade history–social science. California's history is intimately intertwined with its geography, and grade-four students ask questions about the forces shaping California's landscape. In IS3 (Sculpting Landscapes), students observe weathering and erosion on their schoolyard and then create a physical model of a river that they can observe. They use this physical model to develop a conceptual model of how rocks form at Earth's surface, including the deposits of gold that were so important to California history. Students use their model in an engineering connection to design solutions that minimize erosion and protect property today.

California's historical earthquakes provide a tangible phenomenon for studying the energy of waves. In IS4 (Earthquake Engineering), students describe the shaking in terms of wave motion. In an engineering connection, they design an earthquake-resistant structure and test it on a shake table.

A vignette in IS5 (Animal Senses) allows students to obtain information about California's diverse habitats and then explain how different living things have specific body parts that help them survive in each habitat. Students then focus on how animals sense their environment (including a snapshot investigating how termites use scents to follow paths).

The framework also prepares students to meet California's future energy challenges. In grade four, students develop the abstract concept of energy through hands-on investigations with toy cars in IS1 (Car Crashes). Students revisit the phenomena of objects colliding in every grade span during the CA NGSS, building more detailed understanding each time. By tracking the flow of energy in a collision, students recognize that energy is never created but is simply transferred from one object to another. In IS2 (Renewable Energy), they recognize that energy for electricity and fuel must come from somewhere and that obtaining that energy can impact the environment. In an engineering connection, students design a renewable energy device such as a windmill or solar heater. They describe how their device converts energy from one form to another while reducing the environmental impact.

Grade Five

Highlighted Phenomena from Grade Five

- Pancakes do not turn brown unless the batter has some sort of fruit or sugar in it.
- The bottom part of a head of lettuce can regrow new leaves when placed in a cup of water without any soil.
- All the water that flows down the drain in the community goes to a local wastewater treatment plant.
- The length of daylight varies systematically throughout the year.

By grade five, students are ready to think more abstractly about the world around them. In IS1, they develop models of matter that is too small to see, and in IS2, they begin to think about these tiny pieces as building blocks of living beings. In IS3, they recall and categorize their knowledge from previous grades about processes that shape Earth into categories so that they can think about Earth as a system. In IS4, they contemplate stars and galaxies that are inconceivably far away.

The investigations in IS1 (What Is Matter Made of?) have a materials science and engineering focus. Students begin with engineering connections to select the most appropriate material for different purposes (e.g., a tall tower versus a decorative sculpture for a summer birthday). They use these hands-on investigations to develop a model that shows matter is made of particles too small to be seen. A vignette illustrates how students can apply this model to a chemical engineering problem: how do you create the perfect pancake?

In IS2 (From Matter to Organisms), students use their model of matter to explain patterns they observed in previous grades about the needs of living things. They explain the observation that plants can grow without soil and trace the cycling of matter within an ecosystem. In a snapshot, students observe decomposition in nature and design a compost system for their school garden and home.

Instructional segment 3 (Interacting Earth Systems) describes how to use direct investigation of a small ecosystem on the schoolyard to introduce the idea that the planet itself can be thought of as a system made of smaller, interconnected subsystems. Students explore interactions between Earth's people (anthrosphere), land (geosphere), and water (hydrosphere) as they map the runoff of rain falling on their schoolyard as it picks up trash and pollutants. They then investigate how pollutants are naturally filtered out as water soaks through layers of earth. Students engage in an engineering connection to design their own water filtration system.

In IS4 (Patterns in the Night Sky), students turn their eyes skyward to ask questions such as, How far away are the stars, and how can we tell? They begin to answer these questions using a flashlight on their schoolyard or in their classroom as a physical model of the star. They make careful measurements of the patterns of the motion of the stars and discover that, like the Sun, their motion follows a consistent pattern every day and throughout the year. Students will build on this experience when they explain these patterns in the middle grades.

Middle Grades

The CA NGSS provide two possible sequences for science in grades six through eight. The two sequences both support instruction in all of the middle grades CA NGSS. Local districts determine which sequence best meets the needs for their students.

The Preferred Integrated model interweaves science disciplines in a developmentally appropriate progression. In the Discipline Specific model, each grade level focuses in depth on a different science discipline. The framework provides detailed visions for how these models might look in a classroom. The Discipline Specific chapter emphasizes the shift to student-centered, phenomena-based instruction while the Preferred Integrated chapter highlights how different disciplines of science can be integrated around phenomena and crosscutting concepts.

The Preferred Integrated Model

The framework's Preferred Integrated chapter describes specific examples of phenomena that integrate the disciplines at the right level of complexity for middle grades students. In addition, the Preferred Integrated chapter provides options and guidance so that teachers can select locally-relevant topics that will spark interest in their students.

Each course focuses on a single guiding concept that brings together DCIs and CCCs. Each course is divided into four instructional segments, with each one integrating at least three of the four NGSS disciplines (physical science; Earth and space science; life science; and engineering, technology, and application of science).

What is Integrated Science?

Students use the three dimensions of the CA NGSS to understand the world around them. In the language of the CA NGSS, they "engage with observable phenomena," and teachers organize instruction around these phenomena rather than a specific concept in a field of science. To fully understand some phenomena, students must integrate many disciplines of science. In IS4 of grade seven in the Preferred Integrated model, students consider the phenomenon that the 1994 Northridge earthquake triggered more than 11,000 simultaneous landslides. Students investigate the cause of the landslides in terms of the balance of forces (physical science) and the effect on the landscape (Earth and space science) and ecosystem (life science). They also design solutions that use technology to identify areas of high landslide hazard and minimize risk (engineering, technology, and applications of science).

Integrated Grade Six

Highlighted Phenomena from Integrated Grade Six

- People get thirsty when they eat salty foods.
- It rains and snows a lot in the mountains.
- A horse can make water boil by running around in circles turning a metal cylinder.
- During the last 150 years, the Northern Hemisphere has warmed more than the Southern Hemisphere.
- Hundred-year-old ponderosa pines in one part of the Sierra Nevada foothills tower 150 feet tall, but the same age and same species in South Dakota average just 60 feet tall.

The guiding concept for grade six in the framework is "Systems within organisms and between them are adapted to Earth's climate systems." Students focus on the interaction between living systems and their physical environment and use DCIs from physical science to explain processes within each of these systems.

The world is overwhelmingly complex, so scientists frequently think about the world in terms of systems that they can investigate and model in isolation. How do teachers introduce students to this idea of systems? Instructional segment 1 (Systems and Subsystems in Earth and Life Science) introduces systems thinking with the Biosphere project, an experiment where scientists created a self-contained ecosystem and locked themselves inside. Students then compare that system to other simple systems from everyday life. An engineering connection illustrates that systems do not have to be physical objects; students design a system for recruiting more organ and tissue donors to help people when part of their body system fails. The framework helps teachers guide students to compare the human body and Earth, describing both as systems of interacting subsystems.

In IS2 (Earth System Interactions Cause Weather), students ask what causes different parts of California to experience different weather. By focusing on the energy driving these differences, the framework integrates physical science and Earth and space sciences. One snapshot shows how teachers can use a classic historical experiment to teach about energy conversion (friction allows a horse to make a pot of water boil as it walks in circles around a corral turning a large crank). In a vignette, students investigate changes of states of matter from solid to liquid to gas. They develop sophisticated models of matter and heat and link them to models of the water cycle. Students use their models to explain why it rains and snows so much in California's mountains. The vignette requires students to analyze real-time rainfall data from California as evidence supporting their explanation. They apply their understanding to an engineering connection to determine the optimal location for a wind farm in their city.

Students consider weather patterns from a longer time scale and broader spatial scale in IS3 (Causes and Effects of Regional Climates). They build models of Earth's energy budget by analyzing global temperature and precipitation data. They consider how consistent patterns in climate lead to consistent patterns in the organisms living in ecosystems. A snapshot helps teachers transition from these regional scales to the mechanisms of inheritance and variation that allow organisms to adapt to their environment.

Are humans disturbing this delicate balance between ecosystems and climate because of global warming? Students obtain information about the effects of temperature change on sea level, glaciers, or storm intensity. Students then quantify how Californians have a different impact than people from other parts of the world because of our per-capita energy consumption and fossil-fuel emissions. A snapshot describes a capstone project to monitor and mitigate human impacts on the environment.

Integrated Grade Seven

Highlighted Phenomena from Integrated Grade Seven

- A bicycle tire has low air pressure in the morning, but the air pressure gets higher later in the day after being ridden on hot pavement.
- People get hot when they exercise.
- California's two mountain ranges run parallel to its coastline.
- Over just three days in 1982, heavy rains triggered more than 18,000 landslides in the San Francisco Bay Area.
- A landslide in Northern California blocked the path of steelhead trout returning to their spawning grounds.

The guiding concept in grade seven builds on students' understanding of systems from grade six: "Natural processes and human activities cause energy to flow and matter to cycle through Earth's systems." Students track the cycling of matter and energy in chemical systems (IS1), food webs (IS2), the water cycle (IS2), and the rock cycle (IS3). Near the end of the year, students examine how human activities alter these systems.

What does it mean for a product to be "all natural"? To answer this question in IS1 (Organisms and Nonliving Things Are Made of Atoms), students develop detailed conceptual models of how atoms interact and change as they heat up or are involved in chemical reactions. They use this model to explain everyday phenomena, such as the air pressure in their bike tires, snow-capped mountains rising above hot valley floors, and the transformation of natural resources into synthetic materials and products.

One of the challenges of the CA NGSS is that students must use models of microscopic mechanisms to explain everyday phenomena. A vignette in IS2 (Matter Cycles and Energy Flows through Organisms and Rocks) shows teachers how to guide students through these various scales. They begin at the macroscopic level and observe changes in an ecosystem, zoom in to define the exact molecular changes of photosynthesis, then zoom back out to see how organisms use molecules of food for energy and to build their bodies. In an engineering challenge within the vignette, students design a food calorimeter that measures the amount of energy stored in food. They describe how the device works at both the classroom and molecular scale. Students apply a similar methodology to the physical and chemical changes to rocks.

When students look at a map of California's mountains and valleys, they consider questions about the forces that shaped our state and provide some answers. Students must not only be able to explain these features in terms of plate tectonics, but their explanation should be based on a model that shows how the flow of energy drives the cycling of matter. Instructional segment 3 (Natural Processes and Human Activities Shape Earth's Resources and Ecosystems) describes investigations students can conduct and information they can obtain to help develop such a rich model. Students finish IS3 by applying a similar methodology to explain how the cycling of matter in an ecosystem is also driven by the flow of energy.

After having developed robust models of natural systems, students are ready to apply models to predict and explain changes to those systems in IS4 (Sustaining Biodiversity and Ecosystems Services in a Changing World). Students begin by considering the phenomenon of landslides and their role in shaping the physical environment. In an engineering connection, they design a landslide early warning system that can save lives. Students then consider how a physical change like a mega-landslide event can disrupt an ecosystem. A snapshot describes a student-driven capstone project where students develop a plan to restore a habitat that has been changed by human activities.

Integrated Grade Eight

Highlighted Phenomena from Integrated Grade Eight

- Mass extinctions and species diversification events happen repeatedly in Earth's history.
- Many impact craters on Earth show evidence that rock melted at the impact site.
- A volcano on Saturn's moon, Io, has massive eruptions that repeat about once every 1.5 Earth years.
- Very few dinosaur fossils are found in rock layers slightly below the K-T impact boundary (implying that they may have declined before the major impact).
- Satellite observations of net primary productivity show that plants go through seasonal cycles where productivity peaks in the Northern Hemisphere around July and the Southern Hemisphere around January.

Integrated grade eight builds on the ideas of stability and change introduced at the end of grade seven with the guiding concept: "The processes that change Earth's systems at different spatial scales today also caused changes in the past." The framework describes a conceptual flow in which students explain different episodes of mass extinction and species diversification during the first three instructional segments and then move to present-day changes in IS4. The course begins with students analyzing data about the diversity of species over the last 500 million years, which reveals evidence of several mass extinction events.

In IS1 (Objects Move and Collide), students address one possible explanation of the mass extinctions: impact by an asteroid. A snapshot shows how a computer simulation helps students develop models of forces and motion. In an engineering connection, students revisit the phenomena of car crashes from grade four. They design a bumper and explain its function in terms of energy transfer, a common theme throughout IS1. Students revisit the idea of extinction by asteroid impact and look for evidence of energy transfer at an impact site.

Instructional segment 2 (Noncontact Forces Influence Phenomena) also uses phenomena from space to help students develop models of noncontact forces (gravity, magnetism, and electric fields). Noncontact forces can be difficult to visualize, so the framework illustrates how teachers can complement hands-on investigations with physical and computational models. In a snapshot, students analyze and interpret data to determine which forces cause gigantic volcanic eruptions on Jupiter's moon, Io.

Students investigate one mass extinction event in detail by reading fossil evidence in layers of rock like pages of a history book during IS3 (Evolution Explains Life's Unity and Diversity). To explain why different species exist during each time period, students transition to interpreting data about natural selection and evolution in modern-day organisms. A snapshot on natural selection shows how students can use clothespins in a physical simulation to explain real-life bird population data. Another snapshot describes an interactive computer simulation where students play the role of a genetic engineer of zebrafish as they develop a model of how human hands evolved from fish fins.

A vignette in IS4 (Sustaining Local and Global Biodiversity) emphasizes that natural selection mechanisms continue today in response to human activities. Students engineer devices to track modern sharks using principles of sound, light, and radio waves. Applying tracking data, students develop policy solutions that protect sharks and communicate their solutions to the fishing industry, lawmakers, and beach visitors. To build on students' understanding of light waves, IS4 also includes a snapshot about installing solar panels to convert light energy to electricity. Observations of how solar panel output varies with the angle of the Sun throughout the day and year motivates students to develop a model that explains Earth's seasons.

Integrated grade eight ends with a capstone project in which students investigate an environmental challenge. They must explain how humans influence the environment and design specific and detailed solutions that help solve or mitigate the problem.

The Discipline Specific Model

In the Discipline Specific middle grades sequence, students focus on one domain of science during each grade level:

- Grade Six: Earth and Space Science
- Grade Seven: Life Science
- Grade Eight: Physical Science

The framework's Discipline Specific chapter presents grade-level appropriate phenomena and conceptual flows that build in complexity each year and are developmentally matched to students as they progress through the grades. This guidance supports the expectation that students will achieve a sophisticated understanding in all domains of science even though students studying Earth and space sciences in grade six do not have the same capabilities as they do by grade eight when they engage with physical science.

Discipline Specific Grade Six

Highlighted Phenomena from Discipline Specific Grade Six

- The Moon is attracted by Earth's gravity but does not come crashing down.
- Lake Tahoe typically receives more than 10 feet of snow each winter, while it has only snowed five times in San Diego during the last 125 years.
- The average beef burger takes four times more water to produce than an average soy burger that provides the same number of calories.
- Sediment cores taken from lakes in the Sierra Nevada include an ash layer that matches the chemical composition of rocks of the Long Valley Caldera.
- Underwater mountain ranges are located exactly in the middle of the Atlantic Ocean.

Grade six builds directly on ideas from grade five that Earth can be thought of as a series of interconnected subsystems. The instructional segments in grade six focus on the internal workings of these subsystems and how they interact with one another.

Students begin by putting the Earth system in its context within the solar system. Students recognized patterns in the motion of the Sun, Moon, and stars in earlier grades, and now they are ready to develop a detailed model that explains them. A vignette in IS1 (Earth's Place in the Solar System) presents a variety of models to explain the phases of the Moon, providing examples of how teachers can ensure that students truly grasp the complex spatial relationships and how they affect what people on Earth observe.

Students extend these models in IS2 (Atmosphere: Flows of Energy) by showing how the energy flow in the Earth–Sun system affects Earth's seasons and overall climate. They use the model to explain patterns of temperature and precipitation on Earth, and they begin to ask questions about what has caused the global average temperature to increase so quickly in the last century.

In IS3 (Atmosphere/Hydrosphere: Cycles of Matter), students take on the role of weather forecaster, analyzing data and applying models of how air masses move through the atmosphere and water cycles move through the hydrosphere. Instructional segment 3 emphasizes how humans depend on abundant clean water for drinking and growing food, and students obtain information about the amount of water required to grow different varieties of meats and vegetables so that they can make informed dietary choices. An engineering connection focuses on water quantity as students design a system that diverts water flowing along a street into the groundwater and provides the maximum filtration of that water.

Students learn that every rock records a story in IS4 (Geosphere: Surface Processes). They investigate differences between materials on their schoolyard and use them to ask and answer questions about how rocks form at Earth's surface. In an engineering connection, students design and test different mixtures of concrete. Students then relate the process they used to create the concrete mixtures to the natural processes that create sedimentary rocks.

As far back as grade two, students have been describing California's rugged landscape. In IS5 (Geosphere: Internal Processes), they develop a model of plate motions that they can use to explain why California has mountains and valleys and how this landscape relates to the damaging earthquakes that plague the state. In an engineering connection, students design an earthquake early warning system for California that notifies residents a few seconds before strong shaking reaches their homes.

Discipline Specific Grade Seven

Highlighted Phenomena from Discipline Specific Grade Seven

- Scientists sometimes find isotopic traces of ocean biomass in inland forests (likely transported by bears who caught salmon returning upstream to spawn).
- Maps of the human genome show that about 10 percent of our genetic code matches the genetic code of specific viruses.
- All living organisms have cells that use the same basic structure made out of the same basic materials.
- The diet of the person's mother while she was pregnant may affect the age that person eventually starts puberty.
- During El Niño years, large numbers of sea lion pups have been showing up malnourished and abandoned by their parents on the beaches in Southern California.

The framework presents life science as "systems within systems within systems" in which cells interact to create body systems which interact to create organisms which interact to create ecosystems. The example instructional sequence in the Discipline Specific grade seven begins at the tangible, macroscopic scale of ecosystems, zooms into the level of cells, and then zooms back out again to revisit ecosystems. The section is rich with example phenomena that illustrate important interactions at each scale.

Students begin by describing the interactions between organisms within an ecosystem in IS1 (Interdependent Ecosystems). A snapshot illustrates how students, after reading an informational text about wolverines, can create a food web as a systems model and then predict the effects of human behavior on this system.

Instructional segment 2 (Photosynthesis and Respiration) focuses on two of the most important mechanisms by which matter cycles through ecosystems—the chemical processes of photosynthesis and respiration. A snapshot shows how students develop physical models of these chemical reactions to explain how matter moves from one organism to another.

In IS3 (Cells and Body Systems), students examine where these chemical reactions happen within individual organisms—within the microscopic system of a cell and by interactions between those cells. Systems thinking allows students to predict the impacts of changes to a system. A vignette asks students, What happens when one system breaks down within the human body? and illustrates how teachers can help students develop their systems thinking enough to construct explanations of the consequences.

In IS4 (Evidence of Evolution), students ask and answer questions about how different organisms have similar body systems but vary slightly in body structures. Students then explain the mechanisms that cause this phenomenon during the next several instructional segments. A snapshot in IS5 (Inheritance and Genetics) shows how students can obtain information from an interactive computer lesson to create systems models illustrating how parents pass on their genetic code to offspring in sexual and asexual reproduction. They then examine the arguments in favor of and against genetically modified food in order to develop a model for how genetic code can be modified at human timescales through tangible interventions. Students analyze data in IS6 (Natural Selection) to see how similar modifications occur naturally over much longer timescales. Instructional segment 6 includes a series of snapshots that illustrate how teachers can scaffold instruction to help students analyze different population data and relate it to environmental conditions. Students track how sardine and anchovy populations change in response to El Niño conditions and how organisms, such as moose in Norway and pygmies in the tropics, have body sizes that are well adapted for heat retention in their local climate.

Grade seven culminates in IS7 (Revisiting Ecosystems) with students returning to the ecosystem scale. They apply their understanding of natural changes to predict the effects of rapid changes due to human activities. Students define problems that may result from human activities and design solutions that minimize these impacts. Solutions can be very local and practical, such as the engineering connection in which students design and optimize a compost system to reduce the waste from their school cafeteria.

Discipline Specific Grade Eight

Highlighted Phenomena from Discipline Specific Grade Eight

- A satellite orbiting Earth records a stronger gravitational pull over an area after a heavy rainfall has filled underground aquifers with water than during a drought.
- As students drop heavy objects into a tank of water, the amplitude of the wave depends on the size of the object.
- A car with its radio blasting causes the windows of a neighboring car to rattle.
- A railroad tanker car spontaneously imploded shortly after it was cleaned.
- When specific household powders are mixed together, the mixture heats up.

The physical science course for eighth grade is organized around the crosscutting concept of energy flows, cycles, and conservation. While the goal is for students to master DCIs in physical science, many of the phenomena are drawn from Earth and life sciences so that the course truly serves as a culmination to the middle grades science experience. Each instructional segment focuses on one form of energy and is sequenced such that the most conceptually simple energy form (kinetic) comes first.

An engineering connection in two parts in which students design a car bumper serves as bookends that frame IS1 (Energy of Motion). At the beginning of the instructional segment, students explore and create a first iteration. After a series of investigations into forces and motion throughout IS1, students return to the engineering connection with new eyes. They revise their design and then explain how it works using their new understanding of energy transfer.

Students investigate the factors that affect the pull of gravity in IS2 (Gravity and Energy Related to Position) by analyzing data from hands-on measurements and computer simulations. Analyzing measurements from satellites, students find that the mass of water in an aquifer affects the pull of gravity on the satellite. With this measurement data, they can detect how much water has been pumped out from one year to the next.

Instructional segment 3 (Electric and Magnetic Interactions and Energy) is motivated by understanding how electric motors work. These motors propel modern electric cars, but students can also examine motors by disassembling old electronic appliances. Students discover that motors are filled with magnets. Students perform investigations to understand magnets and electromagnets before engaging in an engineering challenge to design and build their own electric motor and then explain the different stages of energy transfer that make it spin.

How do Wi-Fi or cell phones send our voices and data across the world? In IS4 (Waves Transmitting Energy and Information), students investigate how light interacts with various objects. They obtain information about different technologies to explain how they transmit energy and information.

In IS5 (Thermal Energy and Heat Flow) and IS6 (Chemical Energy and Reactions), students progressively refine their model of matter at the microscopic scale. A vignette in IS5 helps students develop and apply this model as they consider the case of a railroad tanker car that imploded. Students learn how to represent thermal energy as the motion of particles and relate heat flow to the movement of tiny particles. They apply this model in an engineering connection to design a vehicle radiator and communicate why their radiator is better than a competitor's.

Up until this point, students have treated matter as entire particles. Now, they understand that these particles are actually molecules made of individual atoms. In IS6, students use a combination of hands-on investigation and model development to explain how the changing arrangement of these atoms during chemical reactions causes energy to transfer. Students apply their understanding in an engineering connection to design a hand-warming pad.

High School

To design instruction for the CA NGSS, high schools need to consider the three dimensions of science, links to other content areas, engineering design, and environmental literacy all with the ultimate goal of college and career readiness. The framework presents several options for high schools to consider that ensure students have opportunities for rich and engaging experiences in science. These options take advantage of synergistic connections between ideas to make the most of instructional time. These examples are possible starting points—they are not mandates or the only way to design instruction. Districts and schools have the freedom and the responsibility to create a course sequence that meets their local needs.

- Four-Course Model: Each course focuses in depth on a different discipline of science: physics, chemistry, biology/life science, and Earth and space sciences.
- Three-Course Model: Earth and space sciences phenomena motivate in-depth study of other science disciplines. The three courses are titled to emphasize the synergy between disciplines: Physics of the Universe, Chemistry in the Earth System, and The Living Earth.
- "Every Science, Every Year" Model: A three-year sequence that interweaves science domains in a developmentally appropriate progression. The framework describes this model in appendix 4, which provides general guidance rather than a detailed set of instructional segments. While the model is a promising opportunity, schools and districts will need to develop the details of this sequence drawing on locally relevant themes and phenomena.

The Three-Course and Four-Course models in the framework were both written so that the courses can be arranged in any sequence. Schools will need to add connections that draw on prior learning and ensure that their courses build in complexity and rigor as students progress from freshman year to the capstone course.

The Four-Course Model

Each course in the high school Four-Course model focuses on a single discipline of science and describes a sequence of instructional segments that bundle the performance expectations together. The four courses in this model are Physics, Chemistry, Life Science/Biology, and Earth and Space Science. The framework discusses the pros and cons of different sequences of these four courses and is written so it is helpful to teachers regardless of the chosen course sequence.

Life Science/Biology

Highlighted Phenomena from High School Life Science/Biology

- Skin cells are constantly dying, but we do not really notice because the new ones look identical to the old ones.
- A person's internal temperature varies by only a few degrees even as the temperature outside spans as much as 40°C.
- There are many more deer than mountain lions in an ecosystem.
- Adenine and thymine are present in equal amounts in cells.
- Skin cancer is more common in people with a specific gene on chromosome 9.
- Several other species of hominin existed, but our species, homo sapiens, is the only one that survived to today.

The framework's high school life science/biology section articulates the level of depth and complexity that the CA NGSS expect in high school. Compared to the middle grades, high school adds relatively few new concepts but instead provides a richer and deeper understanding of the topics that builds on students' existing knowledge and abilities in all three dimensions of the CA NGSS. The biggest progression is the addition of DNA (middle grades DCIs refer to "genetic information" stored on chromosomes but middle grades students are not expected to be familiar with DNA). In high school, students revisit many of the same DCIs from the middle grades and ask, How does DNA act as a mechanism in this process? High school also assumes deeper engagement with the language of chemistry (especially as students discuss the mechanisms of photosynthesis, respiration, and protein synthesis) and tools of mathematics (e.g., probability in genetics and statistics of populations). High school students are also ready to address stability and change at a new level of sophistication (homeostasis in organisms and carrying capacity within ecosystems). Several activities engage students in algorithmic thinking and computational models of population dynamics.

The framework also provides examples of how engineering fits into a biology curriculum. In an engineering connection in IS5 (Cycles of Matter and Energy Transfer in Ecosystems), students play the role of wastewater engineers to optimize conditions for bacteria to speed up wastewater treatment. They use sugars to represent organic waste, yeast to represent the waste-processing bacteria, and glucose test strips to measure the concentration of waste in the water. Is there an optimal amount of yeast to add? Does the treatment process speed up or slow down when students add air or seal the container? What techniques can they develop for efficiently adding air? This engineering task aids students' understanding of HS-LS-2.B so that they can explain the flow of matter and energy in aerobic and anaerobic conditions (HS-LS2-3), but it also ties strongly to the

EP&Cs. In another engineering connection in IS12 (Adaptation and Biodiversity), students play the role of conservation biologists. They design a captive breeding system for California condors, using a computer simulation to determine how many breeding pairs they will need to support and how quickly they expect the population to recover.

The life science/biology course is divided into 12 instructional segments grouped into four sections. In the first section, **From Molecules to Organisms: Structures and Processes,** students develop models of how molecules combine to build cells and organisms (IS1 [Structure and Function]; IS2 [Growth and Development of Organisms]; IS3 [Organization for Matter and Energy Flow in Organisms]). In the second section, **Ecosystems: Interactions, Energy, and Dynamics,** students zoom out to the macroscopic scale to show how organisms interact (IS4 [Interdependent Relationships in Ecosystems]; IS5 [Cycles of Matter and Energy Transfer in Ecosystems]; IS6 [Ecosystem Dynamics, Functioning, and Resilience]; IS7 [Social Interactions and Group Behavior]). Students return to the role that DNA plays in inheritance during the third section, **Heredity: Inheritance and Variation of Traits** (IS8 [Inheritance of Traits]; IS9 [Variation of Traits]). The class ends tying together interactions at all these scales by explaining evolution and natural selection in **Biological Evolution: Unity and Diversity** (IS10 [Evidence of Common Ancestry and Diversity]; IS11 [Natural Selection]; IS12 [Adaptation and Biodiversity]). A vignette in IS12 illustrates the level of three-dimensional understanding students are expected to exhibit as a capstone of the course.

Chemistry

Highlighted Phenomena from High School Chemistry

- The wick of a candle burns much slower than expected for a flammable string.
- Hot and cold packs look identical on the outside but use different ingredients to “spontaneously” change their temperature warmer or cooler.
- A flask of clear liquid spontaneously turns blue when swirled, but the color quickly fades.
- Chemical fertilizers use ammonia. Ammonia synthesis occurs slowly at room temperature but speeds up at low temperatures.
- Natural gas leaks out of pipelines and releases methane into the air.

The high school chemistry course links the macroscopic nature of matter to the internal structure of the atom, which requires students to understand models of the internal structure of the atom and to be familiar with the periodic table. This section of the framework provides guidance about how to teach a rigorous high school chemistry course that builds this background in tandem with deeper understanding of the macroscopic behavior of matter. In high school, students revisit many of the same DCIs from the middle grades and ask such questions as, How does the internal structure of the atom affect this behavior? High school students are ready to address stability and change at a new level as they study equilibrium. The course also integrates concepts of heat transfer and thermodynamics, which are essential for building further understanding of reaction kinetics (HS-PS1-5) and the ideal gas laws. (The latter is a topic that teachers can either include in a high school course or simply lay a foundation for more advanced study.)

The framework also provides examples of how engineering fits into a chemistry curriculum. In an engineering connection in IS5 (Conservation of Energy and Energy Transfer), students design a food calorimeter and iteratively improve the design so that it captures as much of the heat energy from the food as possible. As students engage in the engineering task, they enhance their understanding of energy transfer. In a vignette in IS4 (Modifying Chemical Reactions), students play the role of chemical engineers faced with the societal need to grow enough food to feed the world's people. They improve the efficiency of a chemical reaction for making synthetic fertilizers by adjusting the physical conditions under which the chemical reaction occurs. The problem transcends disciplinary boundaries as students consider the environmental impacts of these synthetic fertilizers washing into local streams and propose solutions to that problem.

The chemistry course is divided into five instructional segments organized around the relevant physical science DCIs following a conceptual flow that builds in complexity. Students begin with a macroscopic view of the properties of matter in IS1 (Properties of Matter). They explain those properties in terms of the internal structure of atoms and chemical bonding in IS2 (Structure of Matter). They investigate basic chemical reactions in IS3 (Understanding Chemical Reactions) and then further complexities of equilibrium and reaction kinetics in IS4 (Modifying Chemical Reactions). In IS5 (Conservation of Energy and Energy Transfer), students explain energy transfer during chemical reactions and return to the macroscopic scale to discuss thermodynamics and heat transfer.

Physics

Highlighted Phenomena from High School Physics

- Cars and mountains both "crumple" during collisions.
- A baseball changes directions when it collides with a bat.
- When a stone is thrown into a pond, ripples fade out as they move away from the central point where the stone sank.
- Four million people die each year in developing countries from illnesses related to inhaling smoke from indoor cooking fires.
- Ultraviolet (UV) light causes sunburn.

The framework's high school physics section articulates the level of depth and complexity that the CA NGSS expect in high school. It provides a richer and deeper understanding that builds on the knowledge and abilities in all three dimensions of the CA NGSS students achieved in the middle grades. Most notably, high school students quantify the observations and models they made in the middle grades. For example, in a snapshot in IS1 (Forces and Motion), students use frame-by-frame video analysis to measure the speed of a baseball and bat to determine the speed of the ball before and after the two collide. Can they predict the speed with which the ball will rebound? The framework describes how this quantification can be accomplished using different levels of mathematical rigor so that teachers could design a freshman physics class or a capstone physics class that equally meet the CA NGSS at a developmentally appropriate level.

The framework also provides examples of the synergy between physics and engineering design. An engineering connection in IS1 (Forces and Motion) describes how to emphasize engineering design and the three dimensions of CA NGSS in a classic egg-drop challenge. Students revisit phenomena of objects colliding in every grade span during the CA NGSS, building more detailed understanding each time. The high school version explains the results in terms of momentum, includes explicit strategies for comparing multiple solutions during the engineering design process (including the environmental impacts of the materials), and could even include computer simulations of prototypes. Students depict their solution as a system in a pictorial model and analyze the forces within the system. Students then explicitly relate their solution to real-life technologies for reducing the impact of collisions such as helmets, air bags, catcher's mitts, or parachutes. In high school, students use engineering to analyze global challenges. In a vignette in IS3 (Energy), students obtain information about the health and environmental impacts of indoor cooking fires in developing countries. They analyze the problem and develop a solar cooker as a replacement. As students engage in the engineering task and refine their design, they enhance their understanding of the forms of energy and energy transfer.

The physics course is divided into four instructional segments organized around the relevant physical science DCIs that follow a conceptual flow that builds in complexity. IS1 (Forces and Motion) starts with simple applications of Newton's laws. In IS2 (Types of Interactions), students investigate gravitational and electromagnetic interactions. Instructional segment 3 (Energy) focuses on energy transfer in all types of interactions. Students then progress to studying the nature of light and applications of waves in IS4 (Waves and Electromagnetic Radiation).

Earth and Space Sciences

Highlighted Phenomena from High School Earth and Space Sciences

- Deep red rocks called banded iron formations were deposited around the world at the time plants first evolved, but they do not form at all today.
- Global average temperatures have been rising over the last 150 years but remained roughly constant for more than a decade in the late 1990s before rising again to record highs.
- The 1994 Northridge earthquake in Southern California was about the same magnitude as a 2003 earthquake in Bam, Iran. About 70 people died in California, but more than 25,000 died in Iran.
- Suburbs with trees can be as much as 40 degrees cooler than urban downtown areas.
- If you look closely enough at a rainbow, certain colors are much dimmer than others.

The framework's high school Earth and space sciences section articulates the level of depth and complexity that the CA NGSS expect in high school. High school students integrate knowledge from physics, chemistry, and biology to understand the mechanisms by which Earth systems interact (e.g., combustion, photosynthesis, and respiration for the carbon cycle; nuclear processes for radiometric dating and stellar fusion; electromagnetic radiation for stellar spectra; gravity for orbital motion). High school also blurs the line between cause and effect as students investigate feedback mechanisms in climate, erosion, and star lifecycles. Students have been expanding the scale of their investigations continuously since kindergarten, and high school students are ready to contemplate and quantify deep timescales by focusing on the age of crustal rocks and the origin of the universe itself.

The framework also provides examples of how engineering applies in an Earth and space sciences curriculum. In an engineering connection for IS2 (Climate), students evaluate how different renewable energy solutions meet society's needs for energy, public health, and environmental protection. In an engineering connection in IS3 (Mountains, Valleys, and Coasts), students design a solution to reduce coastal erosion hazards. Their solution must account for a range of constraints, including cost, safety, reliability, and aesthetics. Students then consider and evaluate the environmental impacts of their design and refine it to reduce those impacts. Students become launch engineers of a weather satellite and employ computer models to examine the tradeoffs between payload mass and fuel cost in IS8 (Motion in the Universe). Other engineering connections revisit challenges that students may have completed with less

complex designs and conceptual understanding in earlier grades such as designing an effective water filter (IS4 Water and Farming) or reducing urban runoff (IS6 Urban Geosciences).

The Earth and Space Sciences course is divided into seven instructional segments that follow a storyline framed around climate change. The course begins with the origin of fossil fuels in IS1 (Oil and Gas) to set up the exploration of climate and global warming in IS2 (Climate). Students consider the impact of climate change as they investigate different Earth system interactions in IS3 (Mountains, Valleys, and Coasts), IS4 (Water and Farming), and IS6 (Urban Geosciences). Students drill down into the solid Earth in IS5 (Causes and Effects of Earthquakes) and turn their eyes skyward in IS7 (Star Stuff) and IS8 (Motion in the Universe). A vignette about urban heat islands in IS6 (Urban Geosciences) illustrates how students can analyze remote sensing data, plan and conduct a hands-on investigation driven by their own research questions, apply what they have learned in an urban design challenge, and conceptualize their understanding in systems models.

The Three-Course Model

The Three-Course model addresses all the CA NGSS standards in fewer years of instruction. Since Earth and space sciences are such interdisciplinary pursuits with crucial importance in California, they make a perfect thread to tie together each of the other high school disciplines. The integration adds value to both disciplines in the pair, with each discipline providing an engaging motivation for and a deeper insight into the other. Earth and space sciences phenomena provide a real-world context for the study of the other disciplines while mastery of general principles within each discipline provides deeper insight into mechanisms that drive change in the Earth system. The three courses have been explicitly titled to emphasize this synergy:

- Living Earth: Integrating Biology and Earth Science
- Chemistry of the Earth System: Integrating Chemistry and Earth Science
- Physics of the Universe: Integrating Physics and Earth and Space Science

The framework discusses the pros and cons of different sequences of these three courses but is written so it is helpful to teachers regardless of the sequence.

The Living Earth

Highlighted Phenomena from High School Living Earth

- When a freeway is built that blocks a population from accessing half its territory, the population shrinks.
- Earth's atmosphere began to decrease in CO_2 and increase in O_2 around the same time that plants first evolved.
- A famous fossil of two dinosaurs fighting formed when the animals were instantly buried by a sudden landslide.
- During the nineteenth century, tuberculous caused as many as 20 percent of all deaths some years. Today, fewer than 250 people in the entire state of California die of the disease in an average year.
- Small animals called pikas are so well adapted to the colder climates of higher elevation that they can overheat in certain temperatures and die in temperatures as low as 80 degrees after a few hours.

This course centers on the biosphere and examines how it interacts with each of the other Earth systems. For example, students define the carrying capacity of an ecosystem in terms of the resources available due to the physical conditions in the geosphere, hydrosphere, and atmosphere. Students investigate the evolution of Earth's atmosphere, which changed dramatically when plants evolved due to photosynthesis and respiration. Students develop a model of how ancient life is recorded in the geosphere as fossils form through Earth's surface processes. They then explain how fossils provide evidence of evolution.

The framework also provides examples of how engineering is incorporated into an integrated Earth and space sciences and life science curriculum. In an engineering connection in IS2 (History of Earth's Atmosphere: Photosynthesis and Respiration), students play the role of wastewater engineers to design a system for protecting the health of local waterways by adding bacteria to decompose organic waste. In another engineering connection, students explore how planting vegetation with root systems can stabilize hill slopes and reduce erosion.

The example instructional sequence begins at the tangible, macroscopic scale of ecosystems in IS1 (Ecosystem Interactions and Energy) and then focuses on specific exchanges of matter and energy within ecosystems in IS2 (History of Earth's Atmosphere: Photosynthesis and Respiration). Students develop models of how changes in the physical environment trigger evolutionary changes that are recorded in the fossil record in IS3 (Evidence of Evolution). Students develop macroscopic models of genetic inheritance in IS4 (Inheritance of traits). Finally in IS5 (Structure, Function, and Growth), students zoom into the detailed mechanisms that enable all the previous interactions to occur. They focus on how cells use DNA to construct proteins, build biomass, reproduce, and create complex multicellular organisms. As a capstone in IS6 (Ecosystem Stability and the Response to Climate Change), students return to the ecosystem scale and see how all these mechanisms interact in the face of Earth's changing climate.

Chemistry in the Earth System

Highlighted Phenomena from High School Chemistry in the Earth System

- A nut or other high-Calorie snack food can light on fire and heat water.
- In demonstration of the second law of thermodynamics, measurements from boreholes show the temperature of rocks is warmer as you probe deeper into Earth.
- Small substitutions of iron into the crystal structure of quartz can cause the normally colorless mineral to be purple. Similar substitutions can be predicted using the periodic table.
- A 2015–16 methane leak from a natural gas storage facility in California is considered "the largest climate disaster in U.S. history" because methane molecules absorb infrared energy and affect Earth's climate.
- The shells of delicate sea creatures called pteropods are dissolving as the ocean has become almost 40 percent more acidic than it was 150 years ago.

In this course, a range of phenomena on Earth motivate the investigation of fundamental principles in chemistry. The link between combustion and climate change is the theme that integrates the sciences in this course. Combustion exemplifies chemical changes, and the combustion of fossil fuels has profound impacts on Earth's systems, including its climate and oceans.

The framework provides examples of how engineering can be incorporated into an integrated chemistry and Earth and space sciences curriculum. Students focus on the chemistry of global energy supplies in an engineering connection IS5 (Chemistry of Climate Change). They define the problem of ocean acidification from the perspective of different stakeholders in IS6 (Dynamics of Chemical Reactions and

Ocean Acidification) and propose specific policy solutions based on the results of computer simulations, hands-on experiments, and information they obtain from online resources.

The course begins with macroscopic observations of matter and chemical reactions in IS1 (Combustion). Students refine their model of the nature of matter by focusing on the level of particles and discussing thermodynamic principles in IS2 (Heat and Energy in the Earth System). They model the transfer of heat between microscopic particles and in macroscopic laboratory systems and then gather evidence that these same processes operate at the scale of the Earth system and drive plate motions. Students then concentrate on the internal structure of the atom and use it to make sense of the periodic table and chemical bonds in IS3 (Atoms, Elements, and Molecules). In IS4 (Chemical Reactions), they refine their models to include chemical energy so that they can explain how foods and fossil fuels can combust to unleash the energy we use in our bodies and machines. In IS5 (Chemistry of Climate Change), students explore the effects of combustion on the Earth system from the chemical perspective, treating Earth's climate as a thermodynamic system and examining how molecules with certain structures can disrupt the flow of energy in this system. They end the course studying chemical equilibrium between the air, water, and carbonate shells of ocean creatures in IS6 (Dynamics of Chemical Reactions and Ocean Acidification). As humans combust more fossil fuels and emit more CO_2, the ocean becomes more acidic. Students engage in a capstone research project to predict the impact of this change on all Earth's systems, including humans who depend on ocean life for food.

Physics in the Universe

Highlighted Phenomena from High School Physics in the Universe

- The hood of a car crumples just as mountains form when two plates collide.
- Fossil fuel power plants do not convert 100 percent of the fuel's chemical potential energy into electricity.
- According to radiometric dating, the oldest rocks on the ocean floor are only 280 million years, but the oldest rocks on land are about 4 billion years old.
- Earthquakes usually consist of two pulses of shaking, one which arrives first and is weak while a second arrives later but is usually stronger.
- Hydrogen and helium (atomic numbers 1 and 2) are the most common elements in the universe, yet lithium and beryllium (atomic numbers 3 and 4) are among the least common elements in the top six rows of the periodic table.

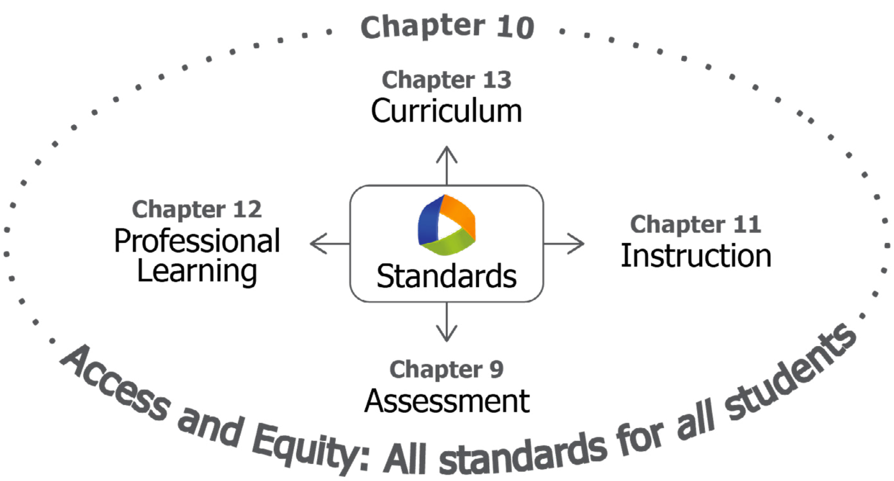
The framework emphasizes the synergy between physical science and Earth and space sciences by focusing on electricity production. The first part of this course builds the conceptual understandings in physics that students need to understand how various power plants work, including fossil fuel, nuclear, wind, hydroelectric, and solar photovoltaic. Students then discuss the impacts that each technology has on different Earth systems and use other Earth and space sciences phenomena to motivate further study of physical science.

In addition to this overall theme, the framework provides examples of engineering embedded in an integrated Earth and space sciences and physics curriculum. In an engineering connection in IS1 (Forces and Motion), students test the strength of different optimal materials to see how much force they can withstand before they break and try to select materials for different applications based on cost and other factors. As students learn about orbits of planetary bodies, they engage in an engineering connection to modify computer codes that calculate orbital paths to determine the initial launch speed and fuel cost for different size payloads.

Instructional segment 1 (Forces and Motion) begins with Newton's laws and an emphasis on collisions caused by plate motions. Students further develop understanding of force in IS2 (Forces at a Distance) when they perform calculations involving gravity and electromagnetism. Instructional segment 3 (Renewable Energy) is the core of the course where students apply DCIs about energy conversion to understand electric power generation. In IS4 (Nuclear Processes and Earth History), students develop a model of how the internal structure of the atom changes during nuclear processes, how these changes release energy, and how these processes are the timekeepers of geologic history. Earthquakes are a tangible phenomenon that introduce the study of waves in IS5 (Waves and Electromagnetic Radiation). Building on this example of mechanical waves, students analyze stellar spectra to understand electromagnetic waves. Patterns in these spectra provide evidence about how stars work and the history of the universe in IS6 (Stars and the Origins of the Universe).

Topic-Specific Guidance

The remaining chapters of the framework outline the other elements necessary for effective implementation of the standards. These chapters support teachers, administrators, and other educators as they implement the CA NGSS. A brief summary of each chapter is provided in this section. The framework also includes five appendixes to support specific aspects of three-dimensional science instruction and learning.



Assessment of Student Learning

Teachers need three-dimensional assessments to assess three-dimensional learning. The framework treats assessment like science: teachers plan and conduct investigations about student learning and analyze the results for patterns in student understanding and misunderstanding. Like scientific investigations, these assessments answer specific questions about student learning and take different investigative forms. For example, performance tasks can include a rich context in which students obtain information about the problem, collect and analyze data, and produce some sort of deliverable. Each step of these multicomponent tasks could provide evidence of student learning, so how does a teacher design engaging tasks that provide meaningful information?

The chapter lists questions that help teachers define the focus of their assessment, presents a conceptual framework for designing assessments, and provides example assessments. In addition to two detailed performance tasks (a hands-on task for elementary students and a case study with embedded data for secondary students), the chapter includes examples of individual tasks designed for specific grade spans and organized by SEPs. Since three-dimensional assessment of the CA NGSS is complex and no assessment is perfect, each example includes commentary about how well the task assesses each of the three dimensions. The examples also include scoring rubrics, when appropriate.

Access and Equity

The framework charts a path for "all students to achieve all standards." This chapter describes several groups with specific learning needs that must be addressed in the science classroom. For each group, the chapter describes how research findings inform strategies that will help students achieve in science and engineering. A series of snapshots illustrates how these strategies look in a classroom.

Instructional Strategies for CA NGSS Teaching and Learning in the Twenty-First Century

This chapter articulates specific strategies that support student-centered, three-dimensional science learning. Rooted in the science of how people learn, the chapter provides strategies for sequencing lessons, engaging student thinking, teaching the nature of science, teaching the engineering design process, using technology, and supporting language demands and mathematical practices within the CA NGSS. The chapter complements the snapshots and vignettes in the grade-level chapters by providing strategies that cut across all areas of science. For example, a teacher motivated by a specific example using science notebooks in a grade-level snapshot can come to this chapter for guidance about the benefits of using notebooks, the types of notebook entries, and how notebooks might be used for engineering challenges.

Implementing High-Quality Science Instruction: Professional Learning, Leadership, and Supports

The framework acknowledges that the CA NGSS are complex and can only be implemented effectively when teachers, school leaders, and school systems work together on this shared vision. The chapter recommends an "ecosystem" approach where physical and human resources both affect the outcome, and the ecosystem evolves over time. This chapter answers questions that support this evolution: What do school leaders need to know to support the CA NGSS? What are effective strategies to enable teachers to become leaders and help one another? How can schools partner with parents and community groups to meet everyone's needs?

Instructional Resources

In the twenty-first century, instructional resources are broadly defined and can include textbooks, kit-based resources, technology-based resources, and open-source electronic resources, among others. With such a broad range of options, how do schools evaluate resources for how well they align to the framework? This chapter defines the specific criteria that the state will use for adopting instructional materials for kindergarten through grade eight and provides guidance about how local educational agencies can select and adopt instructional materials for grades nine through twelve. The criteria go beyond just "meeting the standards" and include alignment with the vision of CA NGSS three-dimensional learning, program organization, assessment, access and equity, instructional planning and support, and additional review of social content that reflects California's multicultural society, avoids stereotyping, and contributes to a positive learning environment.

Appendixes

Progression of SEPS, DCIs, and CCCs in Kindergarten Through Grade Twelve (Appendix 1)

The CA NGSS were designed to deliberately spiral upward as students revisit phenomena and build on their understanding from previous grades. Teachers can see at a glance where their grade level falls within this progression using the tables in this appendix. The tables describe what students should understand and know at the end of each grade span for every subitem in all three dimensions of the CA NGSS (i.e., the SEPs, DCIs, and CCCs).

Connections to Environmental Principles and Concepts (Appendix 2)

This appendix highlights specific CA NGSS performance expectations that offer opportunities to emphasize California's EP&Cs.

Computer Science in Science (Appendix 3)

Computer science plays a central role in modern scientific research and practice and generates economic opportunity in California. This appendix offers an expanded discussion of computer models and computational thinking. It provides three vignettes that illustrate the synergy between computer science and the CA NGSS.

High School Three-Year Model: Every Science, Every Year (Appendix 4)

While the high school chapters of the framework offer two detailed example course models for high school, this appendix includes a sketch of a third option—students learn about every science every year in a developmental progression.

Recommended Literature for Science Classrooms (Appendix 5)

Reading as a tool to extend experiences beyond what otherwise is possible in regular life. This appendix provides examples of how science and reading integrate, offers guidance for how to select science-related texts, and includes a table of example books and stories appropriate for different grade spans.