Appendix III
Disciplinary Core Idea Progression Matrix

Each disciplinary core idea spans pre-K to high school, with each grade span representing a reconceptualization or more sophisticated understanding of how students think about the core idea. In subsequent grades the students' thinking about a disciplinary core idea becomes more sophisticated and closer to a scientific and technical perspective.

The *Framework for K-12 Science Education* (NRC, 2012) provides specific criteria for what constitutes a core idea. To be regarded as core, each idea must meet at least two, though preferably three or four, of the following criteria:

> 1. Have broad importance across multiple sciences or engineering disciplines or be a key organizing principle of a single discipline.
> 2. Provide a key tool for understanding or investigating more complex ideas and solving problems.
> 3. Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge.
> 4. Be teachable and learnable over multiple grades at increasing levels of depth and sophistication. That is, the idea can be made accessible to younger students but is broad enough to sustain continued investigation over years.
>
> NRC, 2012, p. 31

The landscape charts on the following pages present the "progression matrix" and *briefly* describe the content at each grade span for each disciplinary core idea for pre-K–12. The full progressions can be seen in the NRC *Framework*. Strand maps are another way to visualize the progressions (see Appendix IV). This section does not endorse separating the disciplinary core ideas from science and engineering practices in curriculum, instruction, or assessment.

Planning an STE curriculum at any grade level is most effective when it is known what students have already been taught and what they should be learning in subsequent years. This matrix can be helpful in planning and aligning curricula to recognize how standards relate across grade spans, build upon each other, and may be integrated in curriculum. Core ideas do not, however, always define the best units of instruction. Schools and districts will likely group standards in combinations other than those shown in the matrix or in the standards themselves. Organizing the standards by disciplinary core idea provides an opportunity to see how students are supported in learning any one core idea from year to year.

Note that the core ideas for high school physical science are distributed across both introductory physics and chemistry. These are presented next to each other, but they do not represent a sequential progression from introductory physics to chemistry. The dotted line between them is meant to indicate this.

[This appendix draws from and is an adaptation of the NGSS, Appendix E.]

References

National Research Council (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Earth Space Science Progression

INCREASINGLY SOPHISTICATED SCIENCE

<table>
<tr><th></th><th>Pre-K–2</th><th>3–5</th><th>6–8</th><th>9–10</th></tr>
<tr><td rowspan="2">ESS1.A The universe and its stars</td><td rowspan="3">Patterns of movement of the Sun, Moon, and stars as seen from Earth can be observed, described, and predicted.</td><td>Stars range greatly in their distance from Earth and this can explain their relative brightness.</td><td>N/A</td><td rowspan="2">Solar activity creates the elements through nuclear fusion. Astronomical evidence for the Big Bang theory comes from multiple sources.</td></tr>
<tr><td>N/A</td><td>The solar system is part of the Milky Way, which is one of many billions of galaxies.</td></tr>
<tr><td>ESS1.B Earth and the solar system</td><td>The Earth’s orbit and rotation, and the orbit of the Moon around the Earth, cause observable patterns.</td><td>The solar system contains many varied objects held together by gravity. Solar system models explain and predict eclipses, lunar phases, and seasons.</td><td>Kepler’s laws describe common features of the motions of orbiting objects. Changes in Earth’s tilt and orbit result in cycles of climate changes such as ice ages.</td></tr>
<tr><td>ESS1.C The history of planet Earth</td><td>N/A</td><td>Patterns in rock formations and fossils indicate changes in landscapes over time.</td><td>Rock strata and the fossil record can be used as evidence to organize the relative occurrence of major historical events in Earth’s history.</td><td>Past plate motions and plate tectonics explain why continental rocks are so much older than rocks of the ocean floor.</td></tr>
<tr><td>ESS2.A Earth materials and systems</td><td>Wind and water change the shape of the land.</td><td>The water cycle involves interactions of the four major Earth systems. Water, ice, wind, and organisms break rocks, soils, and sediments into smaller pieces and move them around.</td><td>Energy flows and matter cycles within and among Earth’s systems, including the Sun and Earth’s interior as primary energy sources. Plate tectonics is one result of these processes.</td><td>Feedback effects exist within and among Earth’s systems.</td></tr>
<tr><td>ESS2.B Plate tectonics and large-scale system interactions</td><td>Maps show where things are located. One can map the shapes and kinds of land and water in any area.</td><td>Earth’s physical features occur in patterns, as do earthquakes and volcanoes. Maps can be used to locate features and determine patterns in those events.</td><td>Plate tectonics is the unifying theory that explains movements of rocks at Earth’s surface and geological features. Maps are used to display evidence of plate movement.</td><td>Radioactive decay and residual heat of formation within Earth’s interior contribute to thermal convection in the mantle.</td></tr>
</table>

	Pre-K–2	3–5	6–8	9–10
ESS2.C The roles of water in Earth's surface processes	Water is found in many types of places and in different forms on Earth.	Most of Earth's water is in the ocean and much of the Earth's fresh water is in glaciers or underground.	Water cycles among land, ocean, and atmosphere, and is propelled by sunlight and gravity.	The planet's dynamics are greatly influenced by water's unique chemical and physical properties.
ESS2.D Weather and climate	Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region and time. People record weather patterns over time.	Climate describes patterns of typical weather conditions over different scales and variations. Historical weather patterns can be analyzed.	Complex interactions determine local weather patterns and influence climate, including the role of the ocean. Human activities affect global warming.	The role of radiation from the Sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system.
ESS3.A Natural resources	Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do.	Energy and fuels humans use are derived from natural sources and their use affects the environment. Some resources are renewable over time; others are not.	Resources are distributed unevenly around the planet as a result of past geologic processes.	Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits, including to global climate.
ESS3.B Natural hazards	In a region, some kinds of severe weather are more likely than others. Forecasts allow communities to prepare for severe weather.	A variety of hazards result from natural processes; humans cannot eliminate hazards but can reduce their impacts.	Mapping the history of natural hazards in a region helps explain related geological forces.	N/A
ESS3.C Human impacts on Earth systems	Things people do can affect the environment but they can make choices to reduce their impacts.	Societal activities can help protect Earth's resources and environments.	Human activities have altered the biosphere, sometimes damaging it, although changes to environments can have different impacts for different living things. Activities and technologies can be engineered to reduce people's impacts on Earth.	Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources.

Life Science Progression

INCREASINGLY SOPHISTICATED SCIENCE

	Pre-K–2	3–5	6–8	9–10
LS1.A Structure and function	Plants and animals have external parts that they use to perform daily functions.	Organisms have both internal and external macroscopic structures that enable growth, survival, behavior, and reproduction.	All living things are made up of cells. An organism can be made of one cell (unicellular) or many cells (multicellular). Within cells, specialized structures are responsible for specific functions. In multicellular organisms, cells work together to form tissues and organs that are specialized for particular body functions.	Systems of specialized cells within organisms carry out essential functions of life. Any one system in an organism is made up of numerous parts. Feedback mechanisms maintain an organism's internal conditions within certain limits and mediate behaviors.
LS1.B Growth and development of organisms	Parents and offspring engage in behaviors that help offspring survive. Plants and animals have a life cycle.	Reproduction is essential to every kind of organism. Organisms have unique and diverse life cycles, including birth/sprouting, growth, and death.	An organism's structures and behaviors affect the probability of successful reproduction. An organism's growth is affected by both genetic and environmental factors.	In multicellular organisms, the processes of mitosis and differentiation drive an organism's growth and development. Each chromosome pair contains two variants of each gene. Offspring that result from sexual reproduction inherit one set of chromosomes from each parent.
LS1.C Organization for matter and energy flow in organisms	Animals obtain food they need from plants or other animals. Plants need air, water, and light. Plants do not eat food; instead, they make their own "food."	Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air and water, and obtain energy from sunlight, which is used to maintain conditions necessary for survival.	Matter cycles between living and non-living parts of an ecosystem. Plants use the energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through cellular respiration, which rearranges molecules and releases energy.	Organisms are constantly breaking down and reorganizing matter. The hydrocarbon backbones of sugars produced through photosynthesis are used by organisms to make amino acids and other macromolecules that can be assembled into proteins or DNA. During cellular respiration, the bonds of macromolecules and oxygen are broken down to build new products and transfer energy.

	Pre-K–2	3–5	6–8	9–10
LS2.A Interdependent relationships in ecosystems	Plants and animals depend on their surroundings to get what they need.	Some animals eat plants for food and other animals eat the animals that eat plants, while decomposers restore some materials back to the soil. These relationships among organisms in an ecosystem are represented by food webs.	Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors, any of which can limit their growth. Organisms compete for resources within ecosystems; typical interaction patterns include competitive, predatory, parasitic, and symbiotic relationships.	Ecosystems have carrying capacities resulting from biotic and abiotic factors. The fundamental tension between resource availability and organism populations affects genetic diversity within populations and biodiversity within ecosystems.
LS2.B Cycles of matter and energy transfer in ecosystems	[Content found in LS1.C, LS2.A, and ESS3.A]	Matter cycles between the air, water, and soil and among organisms as they live and die.	The matter that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model the transfer of energy as well as matter among producers, consumers, and decomposers within an ecosystem. The Sun provides the energy for most ecosystems on Earth.	Photosynthesis captures energy in sunlight and stores it in chemical bonds of matter. Most organisms rely on cellular respiration to release energy in these bonds to power life processes. About 90% of available energy is lost from one trophic level to the next, resulting in fewer organisms at higher levels. At each link in an ecosystem, elements are combined in different ways and matter and energy are conserved. Photosynthesis, cellular respiration and decomposition are key components of the global carbon cycle.

	Pre-K–2	3–5	6–8	9–10
LS2.C Ecosystem dynamics, functioning, and resilience	N/A	When the environment changes some organisms survive and reproduce, some move to new locations, some new organisms move into the transformed environment, and some die.	Ecosystems are dynamic; their characteristics vary over time. Changes to any component of an ecosystem can lead to shifts in all of its populations. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.	If a biological or physical disturbance to an ecosystem occurs, including one induced by human activity, the ecosystem may return to its more or less original state or become a very different ecosystem, depending on the complex interactions within the ecosystem. The ability of an ecosystem to both resist and recover from change is a measure of its overall health.
LS3.A Inheritance of traits	Young organisms are very much, but not exactly, like their parents and also resemble other organisms of the same kind.	Different organisms vary in how they look and function because they have different inherited information; the environment also affects the traits that an organism develops. Variations of a trait exist in a group of similar organisms.	Organisms reproduce, either sexually or asexually, and parents transfer their genetic information to offspring. An individual's traits are largely the result of proteins, which are coded for by genes. Genes are located in the chromosomes of cells.	Nearly every cell in an organism contains an identical set of genetic information on DNA but the genes expressed by cells can differ. In sexual reproduction, genetic material in chromosomes of DNA is passed from parents to offspring during meiosis and fertilization.
LS3.B Variation of traits			In sexual reproduction, each parent randomly contributes half of its offspring's genetic information, resulting in variation between parent and offspring. Genetic information can be altered because of mutations, which may result in beneficial, negative, or no change to traits of an organism.	The variation and distribution of traits in a population depend on genetic and environmental factors. Sources of genetic variation include gene shuffling and crossing over during meiosis, recombination of alleles during sexual reproduction, and mutations. Mutations can be caused by environmental factors or errors in DNA replication, or from errors that occur during meiosis. Only mutations that occur in gametes can be passed on to offspring.

	Pre-K–2	3–5	6–8	9–10
LS4.A Evidence of common ancestry and diversity	N/A	Fossils provide evidence about the types of organisms and environments that existed long ago. Some living organisms resemble organisms that once lived on Earth.	The fossil record documents the existence, diversity, extinction, and change of many life forms and their environments through Earth's history. Comparisons of anatomical similarities among both living and extinct organisms enables the inference of lines of evolutionary descent.	The fossil record and genetic, anatomical, and developmental homologies provide evidence for common descent among organisms.
LS4.B Natural selection	N/A	Differences in characteristics between individuals of the same species can provide advantages in surviving and reproducing.	Both natural and artificial selection result from certain traits giving some individuals an advantage in surviving, reproducing, and passing on genes to their offspring, leading to predominance of these advantageous traits in a population.	Natural selection, including the special cases of sexual selection and coevolution, works together with genetic drift and gene flow (migration) to shape the diversity of organisms on Earth through speciation and extinction.
LS4.C Adaptation	Different places on Earth each have their own unique assortment of organisms.	Particular organisms can only survive in particular environments. In any environment, some kinds of organisms, and some individuals of a given species, survive better than others.	An adaptation is a trait that increases an individual's chances of surviving and reproducing in their environment. Species can change over time in response to changes in environmental conditions through adaptation by natural selection acting over generations.	Evolution by natural selection occurs when there is competition for resources and variation in traits that lead to differential ability of individuals to survive, reproduce, and pass on genes. As the environment changes, so, too, do the traits that confer the strongest advantages.

Physical Science Progression

INCREASINGLY SOPHISTICATED SCIENCE

	Pre-K–2	3–5	6–8	9–10 (Introductory Physics)	10–11 (Chemistry)
PS1.A Structure of matter (includes PS1.C, nuclear processes)	Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Matter can be divided into smaller pieces, even if it can't be seen. Objects can be built up from smaller parts.	Because matter exists as particles that are too small to see, matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.	That matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, how mixtures will interact, states of matter, phase changes, and conservation of matter. States of matter can be modeled in terms of spatial arrangement, movement, and strength of interactions between particles. Characteristic physical properties unique to each substance can be used to identify the substance.	N/A	The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter. Repeating patterns of the periodic table reflect patterns of sub-atomic structure and can be used to predict properties of elements and classes of chemical reactions. Atoms are conserved in a reaction; thus the mass does not change.
PS1.B Chemical reactions	Heating and cooling substances cause changes that are sometimes reversible and sometimes not.	Chemical reactions that occur when some substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.	Some mixtures of substances can be separated into component substances. Reacting substances rearrange to form different molecules with different properties, but the number of atoms is conserved. Some reactions release energy and others absorb energy depending on the type and concentration of reactants.	N/A	Chemical processes and reaction rates are understood in terms of collisions of molecules, rearrangement of atoms, and changes in energy as determined by properties of elements involved. Knowledge of conservation of atoms with chemical properties and electrical charges can be used to describe and predict chemical reactions. Main types of reactions include transfer of electrons (redox) or

	Pre-K–2	3–5	6–8	9–10 (Introductory Physics)	10–11 (Chemistry)
					hydronium ions (acids/bases). Changes in pressure, concentration, or temperature affect the balance between forward and backward reaction rates (equilibrium). Ionic and covalent bonds can be predicted based on the types of attractive forces between particles.
PS2.A Forces and motion	Pushes and pulls can have different strengths and directions, and can change the speed or direction of an object's motion or start or stop it. Bigger pushes and pulls cause bigger changes in an object's motion.	The effect of unbalanced forces on an object results in a change of motion. Some forces act through contact; some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force.	Newton's second law *(F = ma)* and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.	N/A
PS2.B Types of interactions			Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object. Solutes can change the properties of solvents by creating charged particles.	Forces at a distance are explained by fields that can transfer energy and can be described in terms of the arrangement and properties of interacting objects and the distance between them. These forces can be used to describe the relationship between electrical and magnetic fields.	Electrical forces between electrons and the nucleus of atoms explain chemical patterns. Intermolecular forces determine atomic composition, molecular geometry and polarity, and, therefore, structure and properties of substances. The kinetic-molecular theory describes the behavior of gas in a system.

	Pre-K–2	3–5	6–8	9–10 (Introductory Physics)	10–11 (Chemistry)
PS3.A and 3.B Definition and conservation of energy and energy transfer	[Content found in PS3.D]	Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form.	Kinetic energy can be distinguished from the various forms of potential energy. Energy changes to and from each type can be tracked through physical or chemical interactions. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter.	The total energy within a physical system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects).	In a closed chemical system, the transfer of energy involves enthalpy change and entropy change, though the total energy is conserved. Chemical reactions move toward overall stability, toward a more uniform energy distribution and more stable molecular and network structures.
PS3.C Relationship between energy and forces	[Content found in PS2.B]	When objects collide, contact forces transfer energy so as to change the objects' motions.	When two objects interact in contact or at a distance, each one exerts a force on the other, and these forces can transfer energy between them.	Fields contain energy that depends on the arrangement of the objects in the field.	N/A
PS3.D Energy in chemical processes and everyday life	Sunlight warms Earth's surface. Friction warms objects that rub against each other.	Energy can be "produced" or "used" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food.	Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy.	Photosynthesis is the primary biological means of capturing radiation from the Sun.	N/A

	Pre-K–2	3–5	6–8	9–10 (Introductory Physics)	10–11 (Chemistry)
PS4.A Wave properties	Sound can make matter vibrate and vibrating matter can make sound.	Waves are regular patterns of motion, which can be made in water by disturbing the surface. Waves of the same type can differ in amplitude and wavelength. Waves can make objects move.	A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model can explain many phenomena, including sound and light.	The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing.	N/A
PS4.B Electromagnetic radiation	Some materials allow light to pass through, block light (creating shadows), or redirect light.	Objects can be seen when light reflected from their surface enters our eyes.	The construct of a wave is used to model how light interacts with objects.	Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation, including communications and energy generation.	N/A
PS4.C Information technologies and instrumentation	People use devices to send and receive information.	Patterns can allow information to be encoded, sent, received, and decoded.	Waves can be used to transmit digital information. Digitized information is composed of a pattern of "1s" (ones) and "0s" (zeros).	N/A	N/A

Technology/Engineering Progression

INCREASINGLY SOPHISTICATED SCIENCE

	Pre-K–2	3–5	6–8	9–10
ETS1.A Define design problems	Situations that people want to change can be solved through engineering.	A possible solution to a simple problem must meet specified criteria and constraints.	The precision of criteria and constraints is important to an effective solution, as are considerations that are likely to limit possible solutions.	A broad range of considerations, criteria, and constraints must be considered for problems of social and global significance.
ETS1.B Develop solutions	Solutions can be conveyed through visual or physical representations.	Solutions need to be researched and compared.	Parts of different solutions can be combined to create new solutions.	Major problems need to be broken into smaller problems that can be solved separately.
ETS1.C Optimize solutions	Solutions are compared, tested, and evaluated.	Solutions are improved based on results of simple tests, including failure points.	Systematic processes are used to iteratively test and refine a solution.	Criteria, trade-offs, and social and environmental impacts are considered as a complex solution is tested and refined.
ETS2.A Materials and tools	[Content found in PS1.A]	[Content found in PS1.A]	Materials used in technologies are chosen based on the material properties needed for a particular purpose. Physical processing can change the particulate structure of materials and their properties.	Characteristics of material properties can be tested, defined, and graphed. New materials can be synthesized through chemical and physical processes.
ETS2.B Manufacturing	N/A	N/A	The design and structure of any particular technology product reflects its function. Products can be manufactured using common processes controlled by either people or computers.	Manufacturing processes can transform material properties to meet a need. Particular manufacturing processes are chosen based on the product design, materials used, precision needed, and safety. Computers can help with all of these.
ETS3.A Analyzing technological systems	N/A	N/A	Generally, technology systems are built to accomplish specific goals, rely on defined inputs, carry out specific processes, generate desired outputs, and include feedback for control. Major systems are often designed to work together.	Technological systems are often composed of multiple subsystems, in which the output of one subsystem is the input of another.

	Pre-K–2	3–5	6–8	9–10
ETS3.B Technological systems society relies on (examples)	N/A	Technology is the modification of the natural or designed world to meet people's needs, often made of parts that work together.	Three critical systems society relies on are communications, transportation, and structural systems. Components of a communication system allow messages to be sent long distances. Transportation systems move people and goods using vehicles and devices. And structural systems allow for physical structures that meet human needs.	Communications systems can be analog or digital and use various media. Vehicles can be modified for specific purposes and performance characteristics. Structural analysis must account for active and static loads, as well as properties of materials used in their construction.
ETS4.A Using, transferring, converting energy and power in technological systems	NA	[Content found in PS3.A and 3.B]	Machines convert energy to do work. [Content found in PS3.A and 3.B]	Most technological systems use energy and resources to accomplish desired tasks. People continually work to increase the effectiveness and efficiency of these systems. Technological systems often rely on open or closed fluid systems, particularly hydraulic systems to accomplish tasks requiring large forces.
ETS4.B Thermal systems	N/A	N/A	[Content found in PS3.A and 3.B]	Thermal processes and material properties must be considered in the design of certain technologies, particularly buildings.
ETS4.C Electrical systems	N/A	N/A	[Content found in PS2.B]	The use of electrical circuits and electricity is critical to most technological systems in society. Electrical systems can be AC or DC, rely on a variety of key components, and are designed for specific voltage, current, and/or power.