The *Next Generation Science Standards*

A Focus on Physical Science

By Joe Krajcik

What should all students know about the physical sciences? Why should all students have a basic understanding of these ideas? An amazing number of new scientific breakthroughs have occurred in the last 20 years that impact our daily lives: genetics, nanoscience, and digital technologies, among many others. In addition, we have a much greater understanding of how students learn than ever before. With these breakthroughs, both in science and in how students learn science (NRC 2007), the National Research Council developed *A Framework for K–12 Science Education* (NRC 2012) to guide the development of the *Next Generation of Science Standards (NGSS),* scheduled for release this spring, that will provide direction in science teaching and learning. The overall goal of the *Framework* and *NGSS* is to help all learners in our nation develop the science and engineering understanding that they need to live successful, informed, and productive lives and that will help them create a sustainable planet for future generations. The physical science core ideas are critical to this effort.

The NGSS make use of five key ideas from the *Framework:* (1) limited number of core ideas (2) crosscutting concepts, (3) engaging in scientific and engineering practices, (4) the integration or coupling of core ideas and scientific practices to develop performance expectations, and (5) an ongoing developmental process. The scientific and engineering practices and crosscutting concepts have been discussed in earlier NSTA publications (Bybee 2011, Duschl 2012) and are summarized in the sidebar. In addition, an exploration of the life sciences core idea (Bybee 2013) appeared in the February edition of this journal.

In this article, I will focus on the disciplinary core ideas in physical science, the development of those ideas across time, the importance of blending core ideas with scientific and engineering practices to build understanding, and the development of performance expectations.

The *Framework* and the *NGSS* focus on a limited number of core ideas of science and engineering both within and across the science disciplines that are essential to explain and predict a host of phenomena that students will encounter in their daily lives but that will also allow them to continue to learn more throughout their lives. Core ideas are powerful in that they are central to the disciplines of science, provide explanations of phenomena, and are the building blocks for learning within a discipline (Stevens, Sutherland, and Krajcik 2009). By focusing on ideas in depth, students learn the connections between concepts and principles so that they can apply their understanding to as yet unencountered situations, forming what is known as integrated understanding (Fortus and Krajcik 2011). Supporting students in learning integrated understanding is critical as it allows learners to solve real-world problems and to further develop understanding.

The physical science core ideas

The core ideas in physical science will allow learners to answer important questions such as "How can we make new materials?" "Why do some things appear to keep going, but others stop?" and "How can information be shipped around wirelessly." Moreover, many phenomena, regardless of the discipline, require some level of understanding of physical and chemical ideas. An understanding of chemical reactions and the properties of elements and compounds serves as foundational knowledge for the life sciences and the Earth and space sciences. Explaining photosynthesis and respiration depends upon an understanding of chemical reactions. Understanding energy transfer is critical for explaining many phenomena in the life sciences and in the Earth and space sciences. Explaining ideas like photosynthesis and plate tectonics depend upon understanding of energy transfer. Explaining how the planets revolve around the Sun depends on understanding gravitational force. Explaining why some

Practices for K–12 Science Curriculum

- Asking questions (for science) and defining problems (for engineering).
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

Crosscutting Concepts for K–12 Science Education

Patterns. Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying the patterns.

Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships and the mechanisms by which they are mediated is a major activity of science.

Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different sizes, times, and energy scales and to recognize proportional relationships between different quantities as scales change.

Systems and system models. Delimiting and defining the system under study and making a model of it are tools for developing understanding used throughout science and engineering.

Energy and matter: Flows, cycles, and conservation. Tracking energy and matter flows, into, out of, and within systems, helps one understand a system's behavior.

Structure and function. The way an object is shaped or structured determines many of its properties and functions.

Stability and change. For both designed and natural systems, conditions of stability and what controls rates of change are critical elements to consider and understand.

FIGURE 1

Disciplinary Core Ideas in the Physical Sciences

PS1 Matter and its interactions—How can one explain the structure, properties, and interactions of matter?

PS1.A: Structure and Properties of Matter

- PS1.B: Chemical Reactions
- PS1.C: Nuclear Processes

PS2 Motion and stability: Forces and interactions—How can one explain and predict interactions between objects and within systems of objects?

- PS2.A: Forces and Motion
- PS2.B: Types of Interactions
- PS2.C: Stability and Instability in Physical Systems

PS3 Energy—How is energy transferred and conserved?

- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer
- PS3.C: Relationship Between Energy and Forces
- PS3.D: Energy in Chemical Processes and Everyday Life

PS4 Waves and their applications in technologies for information transfer: How are waves used to transfer energy and information?

- PS4.A: Wave Properties
- PS4.B: Electromagnetic Radiation
- PS4.C: Information Technologies and Instrumentation

materials are attracted to each other while others are not depends upon an understanding of electrical forces. Being able to explain why earthquakes can cause so much damage depends on an understanding of energy transfer. As such, a major goal of the *Framework* is for students to see that the underlying cause-and-effect relationships that occur in all systems and processes, whether biological or physical, can be understood through physical and chemical processes. Because the physical science ideas explain many natural and human-made phenomena that occur each day, developing integrated understanding of them is important for all learners and not only those going on to study science in college or interested in a career in science.

The Framework for K–12 Science Education identifies four core ideas in physical science—a blending of chemistry and physics. Figure 1 presents a list of these core ideas.

Core Idea 1: Matter and its Interactions

The first core idea, *PS1 Matter and Its Interactions,* helps students to formulate an answer to the question: "How can one explain the structure, properties, and interactions of matter?" Understanding matter, its properties, and how it undergoes changes is critical to explaining phenomena in physical science and in the life, and Earth and space sciences. This core idea explains phenomena such as a puddle of water evaporating, burning of wood, tarnishing of metal statues, the cycling of carbon in the environment, and why so many diverse and new products can be formed from such a small set of elements. Although the periodic table identifies 118 elements, only a quarter of these are responsible for all the products on Earth; and fewer than 10, including carbon, hydrogen, oxygen, and nitrogen, make up most materials. These materials exist because in chemical reactions, while the various types and number of atoms are conserved, the arrangement of the atoms is changed, explaining the many observable phenomena in living and nonliving systems.

Core Idea 2: PS2 Motion and Stability

"How can one explain and predict interactions between objects and within systems of objects?" The second core idea, *PS2 Motion and Stability: Forces and Interactions,* focuses on helping students understand ideas related to why some objects will keep moving, why objects fall to the ground, and why some materials are attracted to each other while others are not. Supporting students in developing an understanding of the forces between objects is important for describing and explaining how the motion of objects change, as well as for predicting stability or instability in systems at any scale. The *Framework* describes the forces between objects arising from a few types of interactions: gravity, electromagnetism, and the strong and weak nuclear interactions. The *Framework* places an emphasis on these forces being explained by force fields that contain energy that can transfer energy through space. The *Framework,* while not ignoring gravitational forces, places equal weight on helping students understand electrical interactions as the force that holds various materials together. The attraction and repulsion of electric charges at the atomic scale provide an explanation for the structure, properties, and transformations of matter. Although the ideas of force fields and electrical interactions aren't new, their emphasis as critical to explain everyday phenomena is.

Core Idea 3: PS3 Energy

The third core idea, *PS 3 Energy*, answers the question, "How is energy transferred and conserved?" Energy, while difficult to define, explains the interactions of objects using the ideas of transfer of energy from one object or system of objects to another and that energy is always conserved. How is it that power plants can provide energy used to run household appliances? Understanding energy transfer is critical to this idea. Equally important is for students to understand that the total energy within a defined system changes only by transferring energy into or out of the system with the total amount of energy remaining constant—the conservation of energy. Although energy is always conserved, it can be converted to less useful forms, such as thermal energy in the surroundings. Energy transfer and conservation are critical ideas to explain diverse phenomena such as photosynthesis, respiration, plate tectonics, combustion, and various energy storage devices, such as batteries. While all disciplines have energy as an important construct, often energy is not well understood by students.

Core Idea 4: PS4 Waves and Their Applications in Technologies for Information Transfer

The fourth core idea, *PS4: Waves and Their Applications in Technologies for Information Transfer,* is critical to understanding how many new technologies work and how information is shipped around and stored. This core idea introduces students to critical ideas that explain how the sophisticated technologies available today and how various forms of light and sound are mechanisms for the transfer of energy and transfer of information among objects not in contact with each other. As such, this core idea helps to answer the question: "How are waves used to transfer energy and send and store information?" This core idea also stresses the interplay of physical science and technology. Modern communication, information, and imaging technologies are pervasive in our lives today and serve as critical tools that scientists use to explore the many scales that humans could not explore without these tools. Understanding how these pervasive tools work requires that we understand light and sound and their interactions with matter.

Learning develops over time

The *Framework* goes beyond just presenting the final endpoint for each core idea. Rather, the document is structured with grade band endpoints, consistent with what is known about how learning occurs as an ongoing developmental process. A developmental perspective purposefully builds and links to students' current understanding to form richer and more connected ideas over time (NRC 2007). The core ideas discussed above should be developed from elementary through high school as each year student ideas become more sophisticated, allowing them to more completely explain phenomena as well as explain more phenomena. Too often in science education, we have not systematically considered the prior knowledge of children to build deep and more connected understanding from kindergarten through high school; to do so is critical to build understanding that can be used to solve problems.

A developmental approach guides students' knowledge toward a more sophisticated and coherent understanding of the scientific idea (NRC 2007; Corcoran, Mosher, and Rogat 2009). At the elementary level students explore ideas at an experiential level. For instance, they explore which type of materials that they experience can be melted or turned into a solid. Although learners continue to experience phenomena as they continue in their school, ideas that explain these ideas are introduced. Students form a solid grasp of a particle model in fifth or sixth grade to explain phase changes and then refine this model in seventh and eighth grade so they know that the particles are made of atoms or molecules to explain and predict even more complex phenomena such as chemical reactions would be an example of a developmental approach.

Grade band endpoints in *A Framework for K–12 Science Education* show an indication of this progression of ideas across time. As such, the *Framework* presents a coherent picture of how ideas should develop across time. Figure 2 shows a progression for the core idea Structure and Properties of Matter. At each grade band, students develop a conceptual model that they can use to explain phenomena. At the second grade level, students develop a descriptive model that they can use to describe how matter can exist in different phases. As they continue with their schooling, their conceptual model becomes more sophisticated. By the end of secondary school, students have developed an atomic structure model that allows them to use a causal model for explaining the structure of matter.

This growth in understanding is not developmentally inevitable, but depends upon instruction and key learning experiences to support students in developing more sophisticated understanding across time. Reaching these endpoints depends upon the instruction the student receives and how understanding is assessed. To be a complete learning progression, the progression would also need to show how you can move students from one level to the next and how to assess that understanding. These instructional components are not part of the *Framework* but will depend on development of new curriculum materials based on research. (For more on learning progression research, see Smith et al. 2006 and Rogat et al. 2011).

Content (scientific ideas) is not enough!

The *Framework,* however, stresses more than just ideas in the disciplines. The *Framework* also presents the scientific and engineering practices and crosscutting concepts that students need to use in conjunction with core ideas to build understanding. Scientific practices consist of the multiple ways in which science explores and understands the world (Bybee 2011). Crosscutting concepts are major ideas that transverse the various scientific disciplines (Duschl 2012). The *Framework* emphasizes that learning about science and engineering involves the coupling of core ideas with scientific and engineering practices and crosscutting concepts to engage students in scientific inquiry and engineering design. Convincing evidence exists that understanding science will only result when core ideas are blended with scientific and engineering practices and crosscutting concepts (NRC 2007). Just as science is both a body of knowledge and the process whereby that body of knowledge is developed, the learning of science is similar: You cannot learn a core idea without using it with scientific or engineering practices. Therefore, using practices as a means to develop understanding of science ideas should be a regular part of students' classroom experience and is emphasized throughout the *Framework*.

Expressing standards as performance expectations

The *Framework* stresses that standards should emphasize all three dimensions by integrating scientific and engineering practices with crosscutting concepts and disciplinary core ideas to develop performance expectations. Performance expectations require that students demonstrate knowledge-in-use (NRC 2012). As such, NGSS in physical science will be written in terms of performance expectations. Figure 3, Example Performance Expectations in Physical Science,

FIGURE 2

A Progression of Ideas for the Structure and Properties of Matter

By the end of 2nd grade—A Descriptive Model: Matter exists as different substances (e.g., wood, metal, water), and many of them can be either solid or liquid, depending on temperature. Substances can be described and classified by their observable properties (e.g., visual, aural, textural), by their uses, and by whether they occur naturally or are manufactured. Different properties are suited to different purposes. A great variety of objects can be built up from a small set of pieces. Objects or samples of a substance can be weighed, and their size can be described and measured.

By the end of 5th grade—a Particle Model: Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means (e.g., by weighing or by its effects on other objects). For example, a model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations including: the impacts of gas particles on surfaces (e.g., of a balloon) and on larger particles or objects (e.g., wind, dust suspended in air), and the appearance of visible scale water droplets in condensation, fog, and, by extension, also in clouds or the contrails of a jet. The amount (weight) of matter is conserved when it changes form, even in transitions in which it seems to vanish (e.g., sugar in solution, evaporation in a closed container). Measurements of a variety of properties can be used to identify particular substances.

By the end of 8th grade—an Atomic Molecular Model: All substances are made from some 100 different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits. The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter.

By the end of 12th grade—an atomic structure model: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy to take the molecule apart.

(ADAPTED FROM *A FRAMEWORK FOR K–12 SCIENCE EDUCATION: PRACTICES,CROSSCUTTING CONCEPTS, AND CORE IDEAS* [NRC 2012]) shows five possible performance expectations related to *PS1: Matter and Its Interactions.* These five performance expectations blend the core ideas with scientific practices and crosscutting concepts—and suggest that learning across the grades become more sophisticated. Examining the performance expectations, the idea of chemical reactions becomes more sophisticated from elementary to high school, and it allows learners to explain and predict more phenomena.

Concluding thought

Because fewer ideas are presented and developed across K–12 science curriculum and blended with the use of scientific practices and crosscutting elements, the *Next Generation Science Standards* will present a more coherent view of science education. By developing understanding of the Physical Science Core Ideas, students will develop responses to three critical questions: "What is everything made of?" "Why do things happen?" and "How are waves used to transfer energy and information?" Being able to answer these questions will provide students with the conceptual tools to explain phenomena, solve problems, and learn more as needed. Students will begin to build understanding to these questions in the early elementary grades and will continue their development through high school.

The *Framework* and *NGSS* also emphasize the blending of "content" and "inquiry" to build understanding. The performance expectations in the *NGSS* are the endpoints that learners will need to meet. Classroom instruction and curriculum materials will need to not only help students reach these important ideas but also involve learners in using scientific practices blended with the core ideas and crosscutting concepts to develop and apply the scientific ideas. The core ideas and the performance expectations in physical science are especially important as they build foundational ideas for explaining phenomena in other disciplines.

Joe Krajcik (Krajcik@msu.edu) *is a professor of science education at Michigan State University and director of the Institute for Collaborative Research for Education, Assessment, and Teaching Environment for Science, Technology, and Engineering and Mathematics (CREATE for STEM). He served as design team lead for the NRC* Framework *and serves as design team lead for* NGSS.

FIGURE 3

Sample Standards in Physical Science—Kindergarten

(All samples are drawn from the *NGSS* January 2013 public draft.)

K-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

K-PS1-b. **Design and conduct investigations to test the idea that some materials can be a solid or liquid depending on temperature.** [Assessment Boundary: Only a qualitative description of temperature should be used such as hot, cool, and warm.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. • With guidance, design and conduct investigations in collaboration with peers. (K-PS1-a), (K-PS1-b) • Make direct or indirect observations and/or measurements to collect data which can be used to make comparisons. (K-PS1-a), (K-PS1-b) --- **Connections to Nature of Science** **Science Knowledge is Based on Empirical Evidence** • Scientists look for patterns and order when making observations about the world. (K-PS1-a), (K-PS1-b), (K-PS1-c)	**PS1.A: Structure and Properties of Matter** • Different kinds of matter exist (e.g., wood, metal, water) and many of them can be either solid or liquid, depending on temperature. (K-PS1-a), (K-PS1-b)	**Cause and Effect** • Events have causes that generate observable patterns. (K-PS1-b) • Simple tests can be designed to gather evidence to support or refute student ideas about causes. (K-PS1-b)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others. (K-PS1-b)

K.MD.1 Describe measurable attributes of objects, such as length or weight. Describe several measurable attributes of a single object. (K-PS1-a),(K-PS1-b)

K.MD.2 Directly compare two objects with a measurable attribute in common, to see which object has "more of"/"less of" the attribute, and describe the difference. (K-PS1-a),(K-PS1-b)

FIGURE 3, Continued

Sample Standards in Physical Science—Grade 2

2. PS1 Matter and Its Interactions

Students who demonstrate understanding can:

2-PS1-d. Identify arguments that are supported by evidence that some changes caused by heating or cooling can be reversed and some cannot. [Clarification Statement: Examples of reversible changes are melting chocolate or freezing liquids. An irreversible change is cooking food.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world. • Identify arguments that are supported by evidence. (2-PS1-d) --- **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Science searches for cause and effect relationships to explain natural events. (2-PS1-d)	**PS1.B: Chemical Reactions** • Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible (e.g., melting and freezing), and sometimes they are not (e.g., baking a cake, burning fuel). (2-PS1-d)	**Scale, Proportion, and Quantity** • Relative scales allow objects to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). (2-PS1-d)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RI.2.8 Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point(s). (2-PS1-d)

RI.2.10 By the end of year, read and comprehend informational texts, including history/social studies, science, and technical texts, in the grades 2–3 text complexity band proficiently, with scaffolding as needed at the high end of the range. (2-PS1-c), (2-PS1-d), (2-PS1-a)

W.2.8 Describe how reasons support specific points the author makes in a text. (2-PS1-d)

Mathematics –

MP.3 Construct viable arguments and critique the reasoning of others. (2-PS1-d)

Sample Standards in Physical Science—Grade 5

5-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

5-PS1-d. Design and conduct investigations on the mixing of two or more different substances to determine whether a new substance with new properties is formed. [Clarification Statement: Examples of interactions forming new substances can include mixing baking soda and vinegar. Examples of interactions not forming new substances can include mixing baking soda and water.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. • Design and conduct investigations collaboratively, using fair tests in which variables are controlled and the number of trials considered. (5-PS1-d) • Make observations and/or measurements, collect appropriate data, and identify patterns that provide evidence for an explanation of a phenomenon or test a design solution. (5-PS1-c),(5-PS1-d)	**PS1.B: Chemical Reactions** • When two or more different substances are mixed, a new substance with different properties may be formed; such occurrences depend on the substances and the temperature. (5-PS1-d),(5-PS1-e)	**Cause and Effect** • Cause and effect relationships are routinely identified, tested, and used to explain change. (5-PS1-d),(5-PS1-e)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. (5-PS1-c),(5-PS1-d)

Mathematics –

MP.2 Reason abstractly and quantitatively. (5-PS1-d),(5-PS1-b)

5.OA.2 Write and interpret numerical expressions. (5-PS1-d),(5-PS1-e)

4.MD.2 Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale. (5-PS1-d),(5-PS1-e)

FIGURE 3, Continued

Sample Standards in Physical Science—Middle School

MS-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

MS-PS1-d. Develop molecular models of reactants and products to support the explanation that atoms, and therefore mass, are conserved in a chemical reaction. [Clarification Statement: Models can include physical models and drawings that represent atoms rather than symbols. The focus is on law of conservation of matter.] [Assessment Boundary: The use of atomic masses is not required. Balancing symbolic equations (e.g. N2 + H2 -> NH3) is not required.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems. • Use and/or develop models to predict, describe, support explanation, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales. (MS-PS1-a), (MS-PS1-c), (MS-PS1-d) --- **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-d)	**PS1.B: Chemical Reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-d), (MS-PS1-e), (MS-PS1-f) • The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-d)	**Energy and Matter** • Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-d)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-c), (MS-PS1-d),(MS-PS1-g)

Mathematics –

MP.9 Look for and express regularity in repeated reasoning. (MS-PS1-d)

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FIGURE 3, Continued

Sample Standards in Physical Science—High School

HS-PS1 Matter and Its Interactions

Students who demonstrate understanding can:

HS-PS1-i. **Construct an explanation to support predictions about the outcome of simple chemical reactions, using the structure of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions would include the reaction of sodium and chlorine, or carbon and oxygen, or carbon and hydrogen.] [Assessment Boundary: Chemical reactions not readily predictable from the element's position on the periodic table (i.e., the main group elements) and combustion reactions are not intended. Reactions typically classified by surface level characteristics (e.g., double or single displacement reactions) are not intended.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. • Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulation) and peer review. (HS-PS1-e),(HS-PS1-i) -- **Connections to Nature of Science** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-d)	**PS1.B: Chemical Reactions** • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-h),(HS-PS1-i)	**Patterns** • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-i)

Connections to other DCIs in this grade-level: will be added in future version.

Articulation of DCIs across grade-levels: will be added in future version.

Common Core State Standards Connections:

ELA/Literacy –

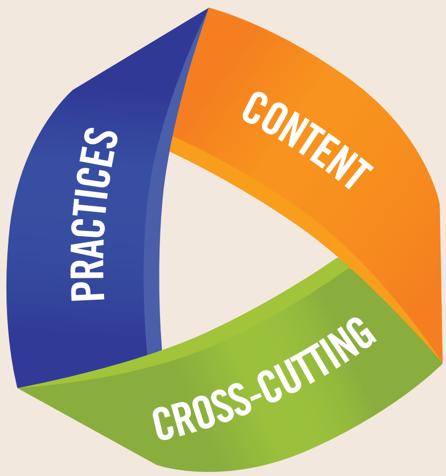
RST.9-10.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (HS-PS1-e), (HS- PS1-i)
RST.9-10.9	Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts. (HS-PS1-e), (HS-PS1-i)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-PS1-e), (HS-PS1-i)
WHST.11-12. 2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-e), (HS-PS1-i)
WHST.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (HS-PS1-a), (HS-PS1-e),(HS- PS1-i)
WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-e),(HS-PS1-i)
SL.9-10.2	Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. (HS-PS1-a), (HS-PS1-c), (HS-PS1-e), (HS-PS1-i)

Mathematics –

S.IC.B	Make inferences and justify conclusions from sample surveys, experiments, and observational studies. (HS-PS1-b), (HS-PS1-e), (HS-PS1-h), (HS-PS1-i)

NGSS @ NSTA

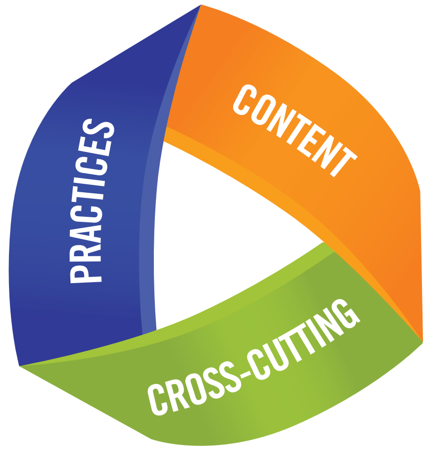
NSTA is publishing articles and books, hosting web seminars, planning conference events, and developing other resources to help science teachers prepare for the *Next Generation Science Standards*. For a complete look at all of the NGSS resources that NSTA has collected, please visit *www.nsta.org/ngss* and click on "Resources." New resources are being added each month, so be sure to bookmark the page and to check back often for the most current NGSS information and analysis.



A look at the *Next Generation Science Standards*

By Ted Willard

The final version of the *Next Generation Science Standards (NGSS)* is expected later this spring. Once it is released, educators across the country will need to carefully study the standards as plans are made for adoption and implementation. The following text and diagram provide an overview on the architecture of the standards.



Overall architecture

NGSS differs from prior science standards in that they integrate three dimensions (science and engineering practices, disciplinary core ideas, and crosscutting concepts) into a single performance expectation and have intentional connections between performance expectations. The system architecture of *NGSS* highlights the performance expectations as well as each of the three integral dimensions and connections to other grade bands and subjects. The architecture involves a table with three main sections.

What is assessed (performance expectations)

A performance expectation describes what students should be able to do at the end of instruction and incorporates a practice, a disciplinary core idea, and a crosscutting concept from the foundation box. Performance expectations are intended to guide the development of assessments. Groupings of performance expectations do not imply a preferred ordering for instruction—nor should all performance expectations under one topic necessarily be taught in one course. This section also contains *Assessment Boundary Statements* and *Clarification Statements* that are meant to render additional support and clarity to the performance expectations.

Foundation box

The foundation box contains the learning goals that students should achieve. It is critical that science educators consider the foundation box an essential component when reading the *NGSS* and developing curricula. There are three main parts of the foundation box: science and engineering practices, disciplinary core ideas, and crosscutting concepts, all of which are derived from *A Framework for K–12 Science Education*.

During instruction, teachers will need to have students use multiple practices to help students understand the core ideas. Most topical groupings of performance expectations emphasize only a few practices or crosscutting concepts; however, all are emphasized within a grade band. The foundation box also contains learning goals for *Connections to Engineering, Technology, and Applications of Science* and *Connections to the Nature of Science*.

Connection box

The connection box identifies other topics in NGSS and in the Common Core State Standards (CCSS) that are relevant to the performance expectations in this topic. The *Connections to other DCIs in this grade level* contains the names of topics in other science disciplines that have corresponding disciplinary core ideas at the same grade level. The *Articulation of Disciplinary Core Ideas (DCIs) across grade levels* contains the names of other science topics that either provide a foundation for student understanding of the core ideas in this standard (usually standards at prior grade levels) or build on the foundation provided by the core ideas in this standard (usually standards at subsequent grade levels). The *Connections to the Common Core State Standards* contains the coding and names of CCSS in Mathematics and in English Language Arts & Literacy that align to the performance expectations.

Ted Willard (twillard@nsta.org) *is a program director at NSTA.*

Inside the NGSS Box

What is Assessed

A collection of several performance expectations describing what students should be able to do to master this standard.

Foundation Box

The practices, core disciplinary ideas, and crosscutting concepts from *A Framework for K–12 Science Education* that were used to form the performance expectations.

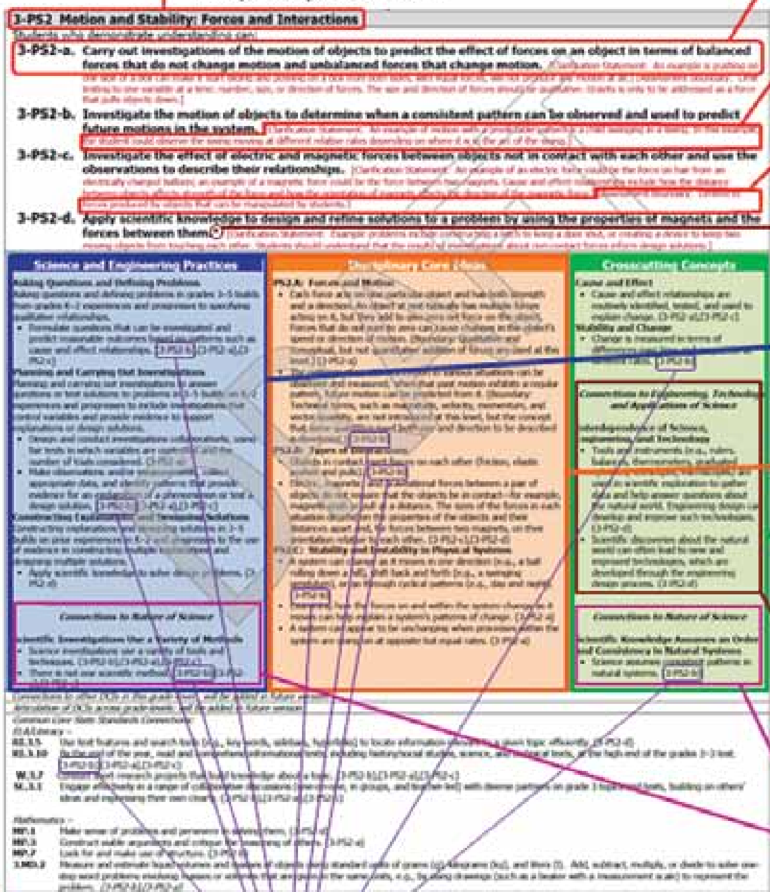
Connection Box

Other standards in the *Next Generation Science Standards* or in the *Common Core State Standards* that are related to this standard.

Based on the January 2013 Draft of NGSS

Title and Code

The titles of standard pages are not necessarily unique and may be reused at several different grade levels. The code, however, is a unique identifier for each set based on the grade level, content area, and topic it addresses.



Codes for Performance Expectations

Codes designate the relevant performance expectation for an item in the foundation box and connection box. In the connections to common core, italics indicate a potential connection rather than a required prerequisite connection.

Performance Expectations

A statement that combines practices, core ideas, and crosscutting concepts together to describe how students can show what they have learned.

Clarification Statement

A statement that supplies examples or additional clarification to the performance expectation.

Assessment Boundary

A statement that provides guidance about the scope of the performance expectation at a particular grade level.

Engineering Connection (*)

An asterisk indicates an engineering connection in the practice, core idea, or crosscutting concept that supports the performance expectation.

Scientific and Engineering Practices

Activities that scientists and engineers engage in to either understand the world or solve a problem.

Disciplinary Core Ideas

Concepts in science and engineering that have broad importance within and across disciplines as well as relevance to people's lives.

Crosscutting Concepts

Ideas, such as *Patterns* and *Cause and Effect*, which are not specific to any one discipline but cut across them all.

Connections to Engineering, Technology, and Applications of Science

These connections are drawn from the disciplinary core ideas for engineering, technology, and applications of science in the *Framework*.

Connections to Nature of Science

Connections are listed in either the practices or the crosscutting connections section of the foundation box.