

Welcome

Book Beat Live: Exploring the Science and Engineering Practices with the NSTA Quick-Reference Guide to the Three Dimensions

June 22, 2022
7:00 PM ET

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NSTA does not allow promotion of other products in our chats during web seminars. We ask that attendees keep the conversation on topic, use positive language and remain courteous of others throughout the event, and allow everyone time to participate in the chat

Meet Today's Presenter



Ted Willard

Senior Subject Matter Expert

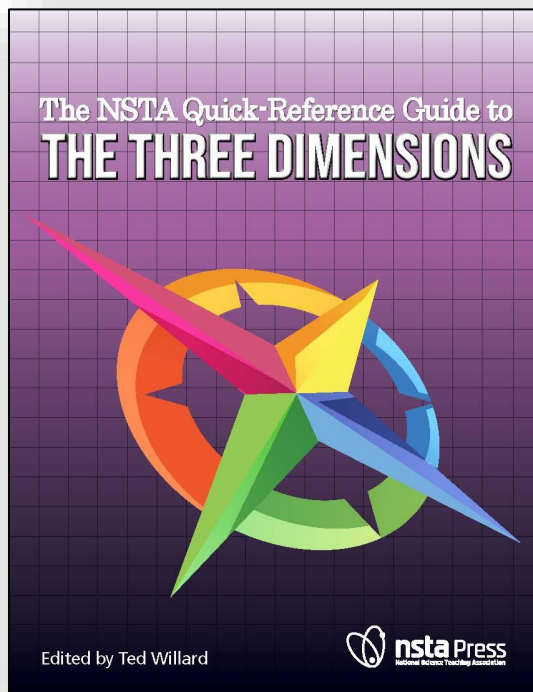
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Exploring the Science and Engineering Practices with *The NSTA Quick-Reference Guide to the Three Dimensions*



NSTA Author Series
Wherever you are 😊
June 22, 2022

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When You Teach 3D

Based on *Just the Way You Are*
by Bruno Mars



When You Teach 3D



(Based on *Just the Way You Are* by Bruno Mars)

Oh, their eyes, their eyes

Class goes so slow when they're not shinin
while they are there,

They're not even really tryin'

They're not interested, and I struggle every day

Yeah, I know, I know

If I give them answers they won't learn it deeply

And it's so, it's so

Sad to think that they don't see what I see

I keep thinking there must be another way

And I say



When You Teach 3D



When they're interested

There're so many things that then can change

Cuz its amazing

When you teach 3D

And it makes you smile

When they are sensemaking for a while

Cuz its amazing

When you teach 3D



When You Teach 3D



Yeah

Now I do know

Another way that I can teach them science

They ask, questions

and seek answers so that it all makes some sense

of the phenomena around them every day

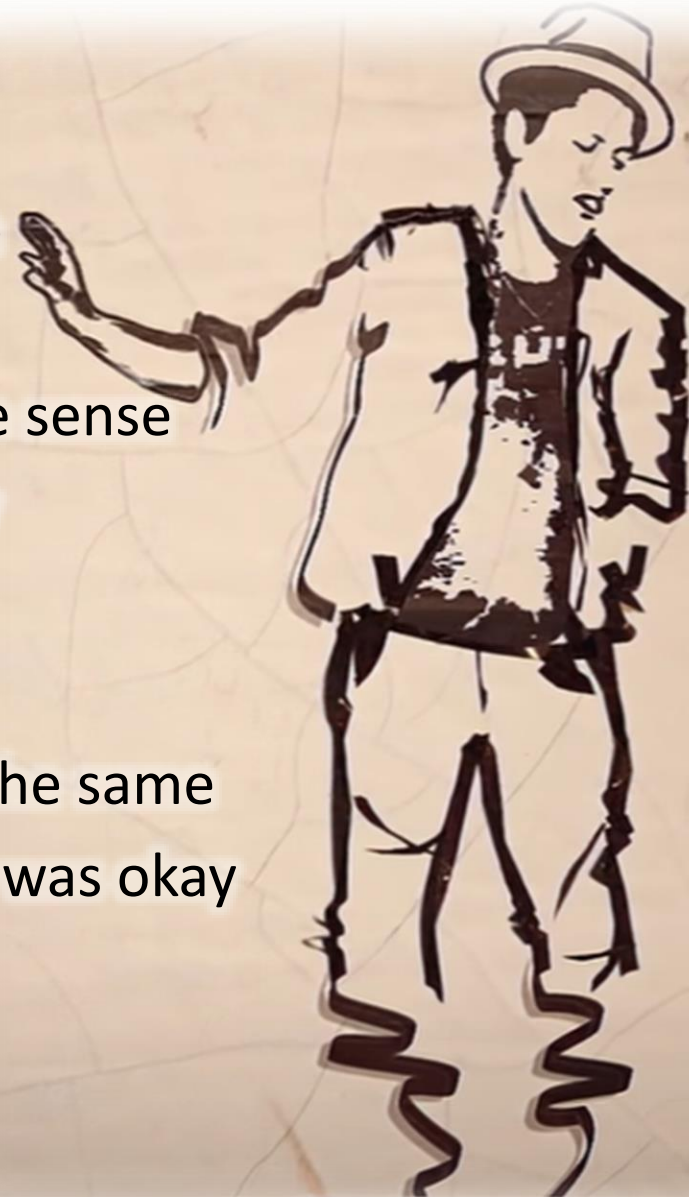
Oh, you know, you know

You know I really needed this change

If I didn't care about the kids, I'd just stay the same

So don't even bother asking if the old way was okay

You know I'll say



When You Teach 3D



When they're interested

There're so many things that then can change

Cuz its amazing

When you teach 3D

And it makes you smile

When they are sensemaking for a while

Cuz its amazing

When you teach 3D

When you teach 3D

When you teach 3D

Cuz its amazing

When you teach 3D



When You Teach 3D



When they're interested

There're so many things that then can change

Cuz its amazing

When you teach 3D

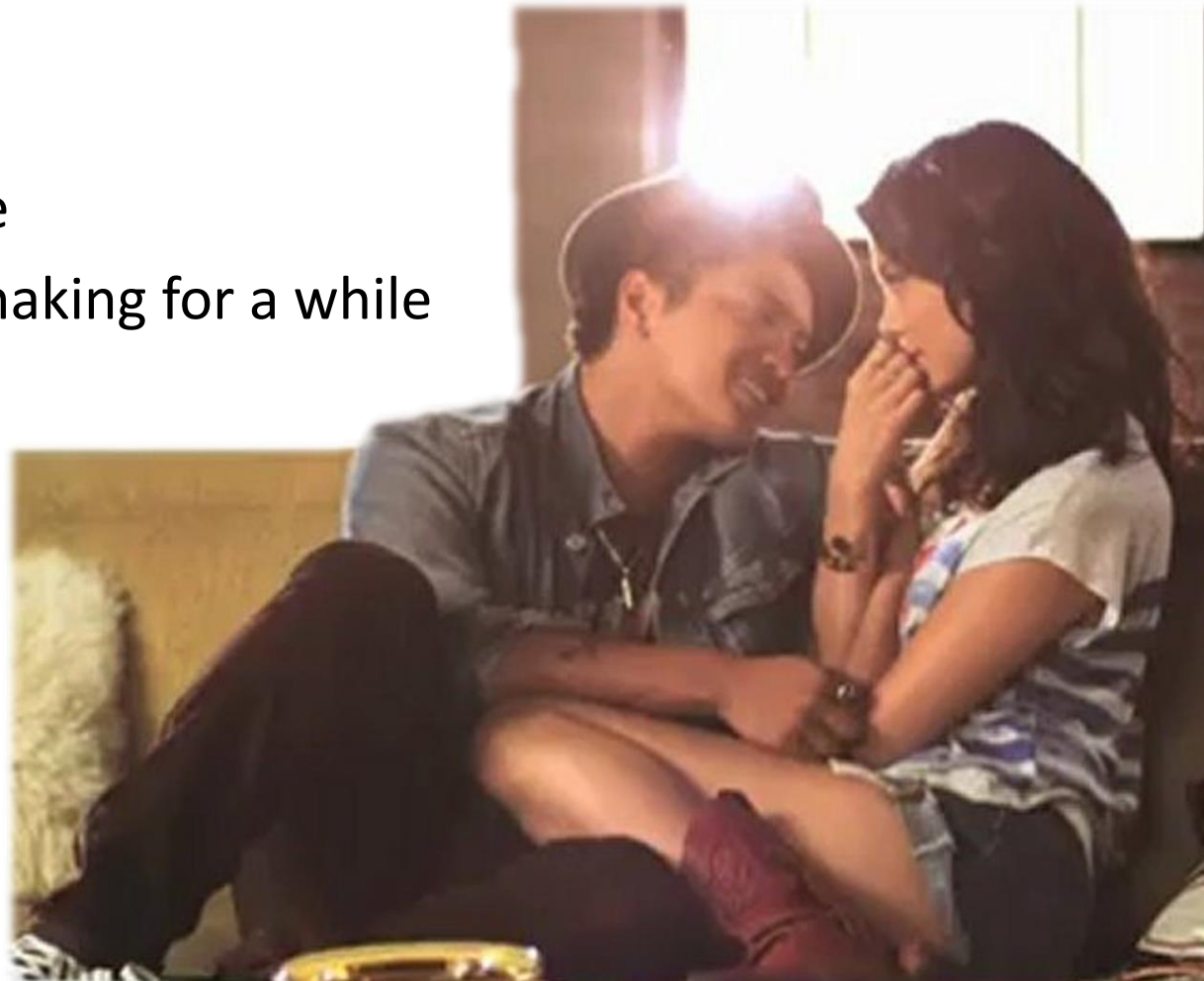
And it makes you smile

When they are sensemaking for a while

Cuz its amazing

When you teach 3D

Yeah

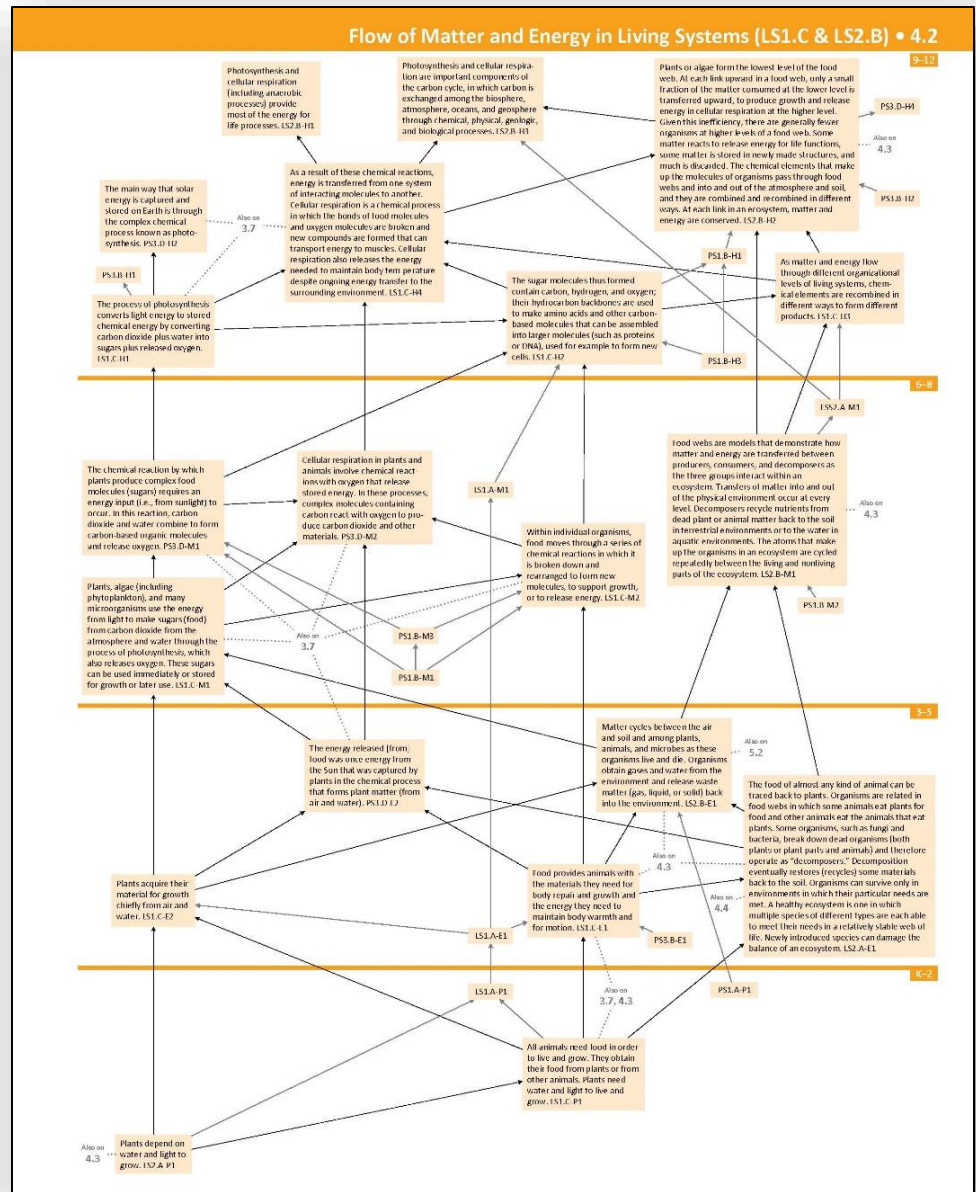
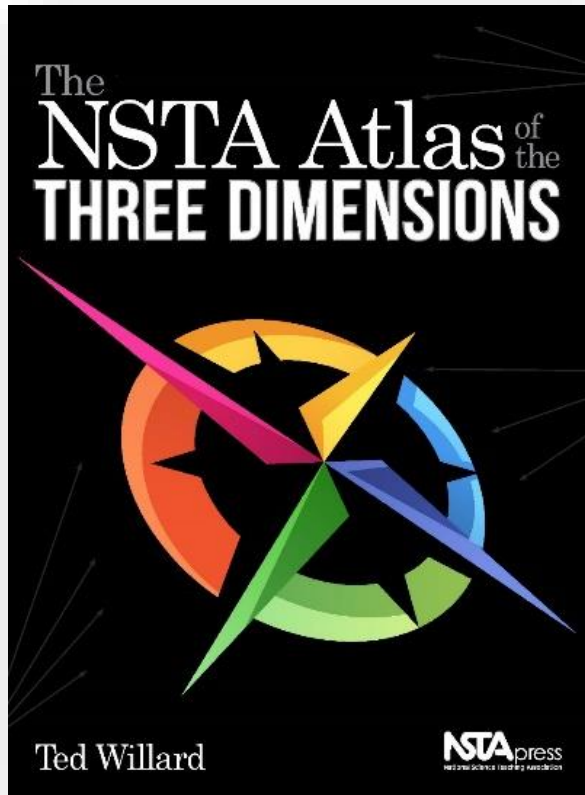


A Little History

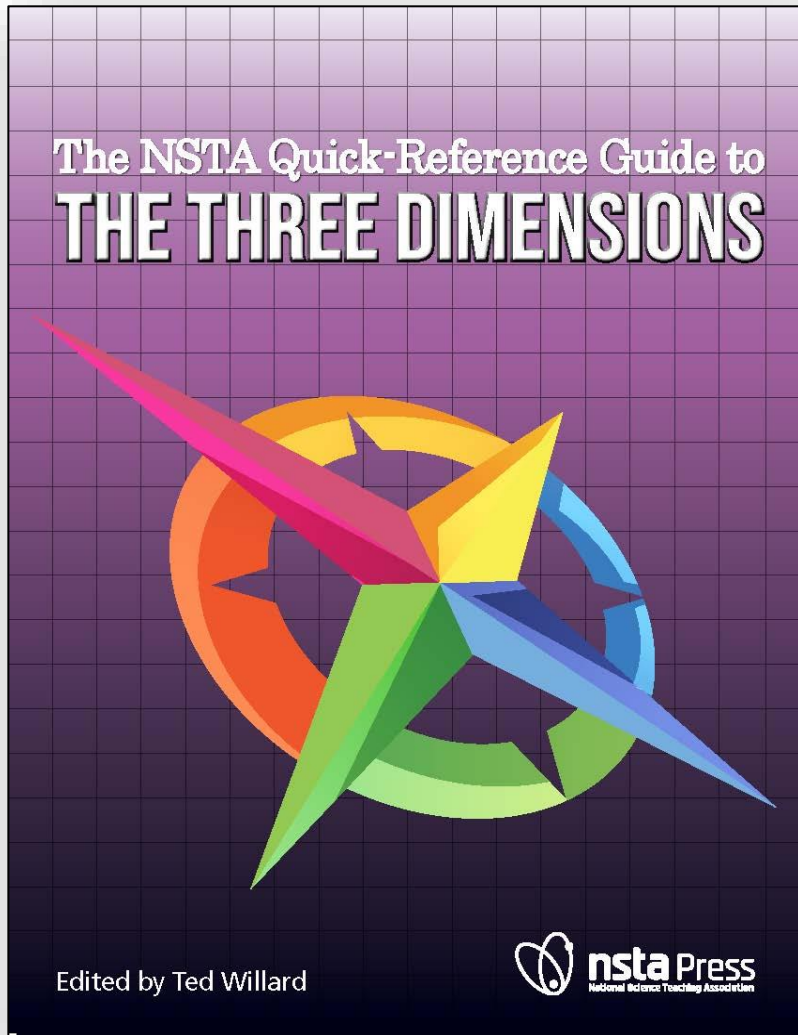
The Original Quick-Reference Guides



The NSTA Atlas of the Three Dimensions



The **New** Quick-Reference Guide



- Greater usability in states that have developed their own standards based on the Framework
- Influenced by work done developing the *NSTA Atlas of the Three Dimensions*
- Better functionality based on the experiences of educators using the original

Basic Tour

Table of Contents



1. Descriptions of the Science and Engineering Practices from the Framework
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1: Descriptions of the Science and Engineering Practices From the *Framework*



CHAPTER 1

Science and Engineering Practice 1: Asking Questions and Defining Problems

Questions are the engine that drive science and engineering.

Science asks

- What exists and what happens?
- Why does it happen?
- How does one know?

Engineering asks

- What can be done to address a particular human need or want?
- How can the need be better specified?
- What tools and technologies are available, or could be developed, for addressing this need?

Both science and engineering ask

- How does one communicate about phenomena, evidence, explanations, and design solutions?

Asking questions is essential to developing scientific habits of mind. Even for individuals who do not become scientists or engineers, the ability to ask well-defined questions is an important component of science literacy, helping to make them critical consumers of scientific knowledge.

Scientific questions arise in a variety of ways. They can be driven by curiosity about the world (e.g., Why is the sky blue?). They can be inspired by a model's or theory's predictions or by attempts to extend or refine a model or theory (e.g., How does the particle model of matter explain the incompressibility of liquids?). Or they can result from the need to provide better solutions to a problem. For example, the question of why it is impossible to siphon water above a height of 32 feet led Evangelista Torricelli (17th-century inventor of the barometer) to his discoveries about the atmosphere and the identification of a vacuum.

Questions are also important in engineering. Engineers must be able to ask probing questions in order to define an engineering problem. For example, they may ask: What is the need or desire that underlies the problem? What are the criteria (specifications) for a successful solution? What are the constraints? Other questions arise when generating possible solutions: Will this solution meet the design criteria? Can two or more ideas be combined to produce a better solution? What are the possible trade-offs? And more questions arise when testing solutions: Which ideas should be tested? What evidence is needed to show which idea is optimal under the given constraints?

The experience of learning science and engineering should therefore develop students' ability to ask—and indeed, encourage them to ask—well-formulated questions that can be investigated empirically. Students also need to recognize the distinction between questions

Descriptions of the Science and Engineering Practices From the *Framework*

that can be answered empirically and those that are answerable only in other domains of knowledge or human experience.

GOALS

By grade 12, students should be able to

- Ask questions about the natural and human-built worlds—for example: Why are there seasons? What do bees do? Why did that structure collapse? How is electric power generated?
- Distinguish a scientific question (e.g., Why do helium balloons rise?) from a nonscientific question (Which of these colored balloons is the prettiest?).
- Formulate and refine questions that can be answered empirically in a science classroom and use them to design an inquiry or construct a pragmatic solution.
- Ask probing questions that seek to identify the premises of an argument, request further elaboration, refine a research question or engineering problem, or challenge the interpretation of a data set—for example: How do you know? What evidence supports that argument?
- Note features, patterns, or contradictions in observations and ask questions about them.
- For engineering, ask questions about the need or desire to be met in order to define constraints and specifications for a solution.

PROGRESSION

Students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. For engineering, they should ask questions to define the problem to be solved and to elicit ideas that lead to the constraints and specifications for its solution. As they progress across the grades, their questions should become more relevant, focused, and sophisticated. Facilitating such evolution will require a classroom culture that respects and values good questions, that offers students opportunities to refine their questions and questioning strategies, and that incorporates the teaching of effective questioning strategies across all grade levels. As a result, students will become increasingly proficient at posing questions that request relevant empirical evidence; that seek to refine a model, an explanation, or an engineering problem; or that challenge the premise of an argument or the suitability of a design.

2: Descriptions of the Crosscutting Concepts From the *Framework*



CHAPTER 2

Descriptions of the Crosscutting Concepts From the *Framework*

Crosscutting Concept 1: Patterns

Patterns exist everywhere—in regularly occurring shapes or structures and in repeating events and relationships. For example, patterns are discernible in the symmetry of flowers and snowflakes, the cycling of the seasons, and the repeated base pairs of DNA. Noticing patterns is often a first step to organizing and asking scientific questions about why and how the patterns occur.

One major use of pattern recognition is in classification, which depends on careful observation of similarities and differences; objects can be classified into groups on the basis of similarities of visible or microscopic features or on the basis of similarities of function. Such classification is useful in codifying relationships and organizing a multitude of objects or processes into a limited number of groups. Patterns of similarity and difference and the resulting classifications may change, depending on the scale at which a phenomenon is being observed. For example, isotopes of a given element are different—they contain different numbers of neutrons—but from the perspective of chemistry they can be classified as equivalent because they have identical patterns of chemical interaction. Once patterns and variations have been noted, they lead to questions; scientists seek explanations for observed patterns and for the similarity and diversity within them. Engineers often look for and analyze patterns, too. For example, they may diagnose patterns of failure of a designed system under test in order to improve the design, or they may analyze patterns of daily and seasonal use of power to design a system that can meet the fluctuating needs.

The ways in which data are represented can facilitate pattern recognition and lead to the development of a mathematical representation, which can then be used as a tool in seeking an underlying explanation for what causes the pattern to occur. For example, biologists studying changes in population abundance of several different species in an ecosystem can notice the correlations between increases and decreases for different species by plotting all of them on the same graph and can eventually find a mathematical expression of the interdependences and food-web relationships that cause these patterns.

PROGRESSION

Human beings are good at recognizing patterns; indeed, young children begin to recognize patterns in their own lives well before coming to school. They observe, for example, that the Sun and the Moon follow different patterns of appearance in the sky. Once they are students, it is important for them to develop ways to recognize, classify, and record patterns in the phenomena they observe. For example, elementary students can describe and predict the patterns in the seasons of the year; they can observe and record patterns in the similarities and differences between parents and their offspring. Similarly, they can investigate the characteristics that allow classification of animal types (e.g., mammals, fish, insects), of plants (e.g., trees, shrubs, grasses), or of materials (e.g., wood, rock, metal, plastic).

These classifications will become more detailed and closer to scientific classifications in the upper elementary grades, when students should also begin to analyze patterns in rates

of change—for example, the growth rates of plants under different conditions. By middle school, students can begin to relate patterns to the nature of microscopic and atomic-level structure—for example, they may note that chemical molecules contain particular ratios of different atoms. By high school, students should recognize that different patterns may be observed at each of the scales at which a system is studied. Thus classifications used at one scale may fail or need revision when information from smaller or larger scales is introduced (e.g., classifications based on DNA comparisons vs. those based on visible characteristics).

3: Tools for Working with Standards



Inside the Standards Box

What Is Assessed
A collection of several performance expectations describing what students should be able to do at the end of instruction

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

Connection Box
Places elsewhere within these standards (or in mathematics or ELA standards) that are connected to the performance expectations on this page

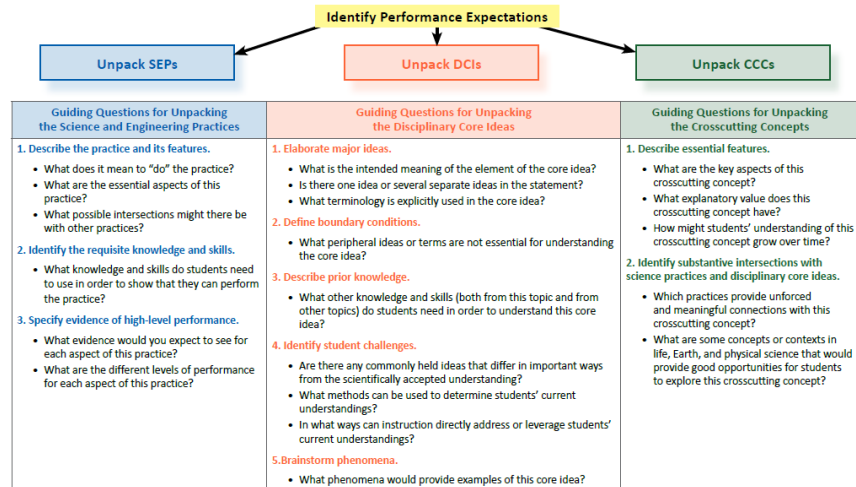
Scientific & Engineering Practices Elements
Activities that scientists and engineers engage in to either make sense of phenomena or to solve a problem

Disciplinary Core Ideas Elements
Ideas in science and engineering that have broad importance within and across disciplines as well as relevance in people's lives.

Crosscutting Concepts
Concepts, such as *Patterns*, *Effect*, which provide important asking questions about phenomena

- Title**
The title for a set of performance expectations. It is not necessarily unique and may be reused at several different grade levels.
- 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 a performance expectation that integrates engineering and technology.

Guiding Questions for Unpacking the Standards



From: *The NSTA Atlas of the Three Dimensions* (Willard, 2020) based on procedures described in *Creating and Using Instructionally Supportive Assessments in NGSS Classrooms* (Harris, Krajcik, and Pellegrino, forthcoming).

4: K–12 Progression of the Elements of the Three Dimensions



The NSTA Quick-Reference Guide to the Three Dimensions

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AQDP: Ask Questions and Define Problems		Science and Engineering Practices	
<i>Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.</i>	<i>Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships.</i>	<i>Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, clarify arguments and models.</i>	<i>Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.</i>
AQDP-P1: Ask questions based on observations to find more information about the natural and/or designed world(s).	AQDP-E1: Ask questions about what would happen if a variable is changed.	AQDP-M1: Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify	AQDP-H1: Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.

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NATIONAL SCIENCE TEACHING ASSOCIATION

CE: Cause and Effect: Mechanism and Explanation		Crosscutting Concepts	
CE-P1: Simple tests can be designed to gather evidence to support or refute student ideas about causes. CE-P2: Events have causes that generate observable patterns.	CE-E1: Cause and effect relationships are routinely identified, tested, and used to explain change. CE-E2: Events that occur together with regularity might or might not be a cause and effect relationship.	CE-M1: Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. CE-M2: Cause and effect relationships may be used to predict phenomena in natural or designed systems. CE-M3: Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.	CE-H1: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CE-H2: Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. CE-H3: Systems can be designed to cause a desired effect. CE-M4: Changes in systems may have various causes that

SPQ: Scale, Proportion, and Quantity

SPQ-P1: Relative scales allow objects and events to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower). SPQ-P2: Standard units are used to measure length.	SPQ-E1: Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods. SPQ-E2: Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.
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SYS: Systems and System Models

SYS-P1: Objects and organisms can be described in terms of their parts. SYS-P2: Systems in the natural and designed world have parts that work together.	SYS-E1: A system is a group of related parts that make up a whole and can carry out functions; its individual parts cannot. SYS-E2: A system can be described in terms of its components and their interactions.
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PS2: Motion and Stability: Forces and Interactions

PS2.A: Forces and Motion		Disciplinary Core Ideas	
PS2.A-P1: Pushes and pulls can have different strengths and directions. PS2.A-P2: Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.	PS2.A-E1: Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.) PS2.A-E2: The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (Boundary: Technical terms, such as magnitude, velocity, momentum, and vector quantity, are not introduced at this level, but the concept that some quantities need both size and direction to be described is developed.)	PS2.A-M1: For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). PS2.A-M2: The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. PS2.A-M3: All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.	PS2.A-H1: Newton's second law accurately predicts changes in the motion of macroscopic objects. PS2.A-H2: Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved. PS2.A-H3: If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.
PS2.B-P1: When objects touch or collide, they push on one another and can change motion.	PS2.B-E1: Objects in contact exert forces on each other. PS2.B-E2: Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. PS2.B-E3: The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	PS2.B-M1: Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. PS2.B-M2: Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the Sun. PS2.B-M3: Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, a magnet, or a ball, respectively).	PS2.B-H1: Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. PS2.B-H2: Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. PS2.B-H3: Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.

K–12 Progressions of the Elements of the Three Dimensions

CHAPTER 4

Elements

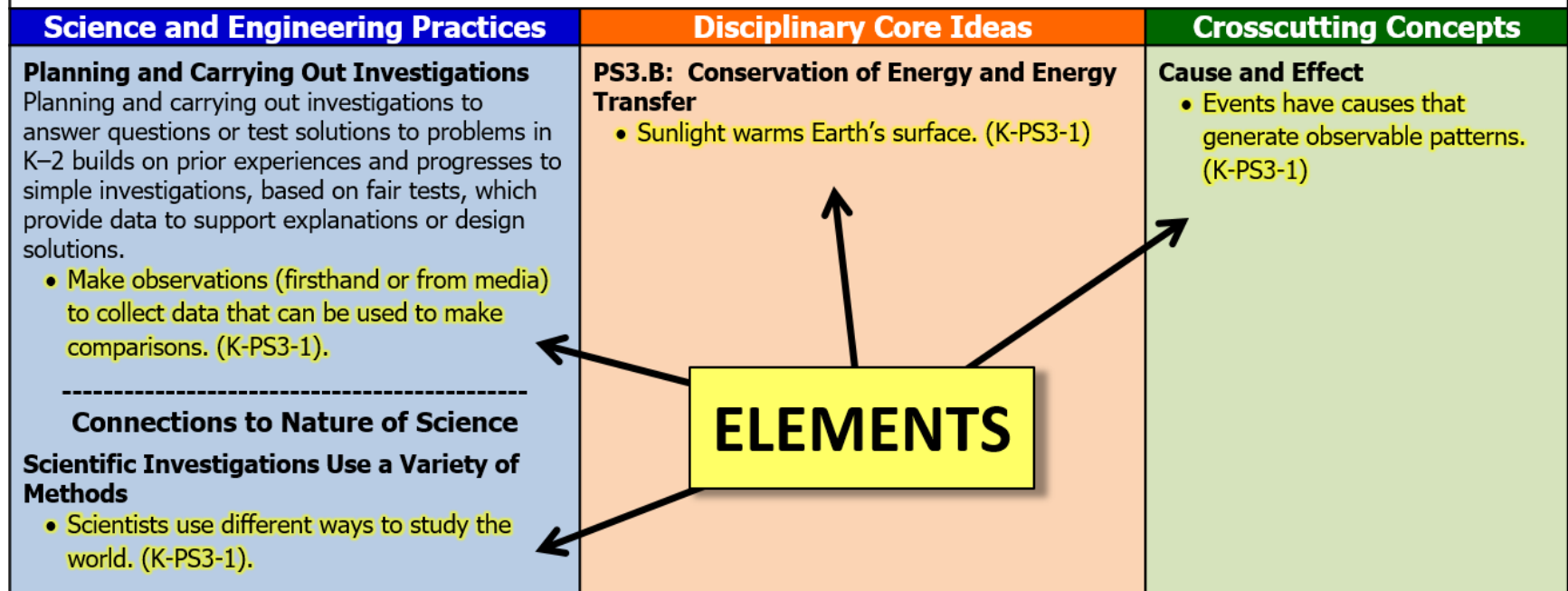


Students who demonstrate understanding can:

K-PS3-1. Make observations to determine the effect of sunlight on Earth's surface.

Clarification Statement: Examples of Earth's surface could include sand, soil, rocks, and water.

Assessment Boundary: Assessment of temperature is limited to relative measures such as warmer/cooler.



4: K–12 Progression of the Elements of the Three Dimensions



Connections to Engineering, Technology, and Applications of Science

<p>INTER: Interdependence of Science, Engineering, and Technology</p>	<p>INTER-P1: People encounter questions about the natural world every day.</p> <p>INTER-P2: Science and engineering involve the use of tools to observe and measure things.</p>	<p>INTER-E1: Science and technology support each other.</p> <p>INTER-E2: Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies.</p> <p>INTER-E3: Scientific discoveries about the natural world can often lead to new and improved technologies, which are developed through the engineering design process.</p> <p>INTER-E4: Knowledge of relevant scientific concepts and research findings is important in engineering.</p>	<p>INTER-M1: Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems.</p> <p>INTER-M2: Science and technology drive each other forward.</p> <p>INTER-M3: Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations.</p>	<p>INTER-H1: Science and engineering complement each other in the cycle known as research and development (R&D).</p> <p>INTER-H2: Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.</p>
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<p>INFLU: Influence of Science, Engineering, and Technology on Society and the Natural World</p>	<p>INFLU-P1: Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials.</p> <p>INFLU-P2: Taking natural materials to make things impacts the environment.</p> <p>INFLU-P3: People depend on various technologies in their lives; human life would be very different without technology.</p>	<p>INFLU-E1: People's needs and wants change over time, as do their demands for new and improved technologies.</p> <p>INFLU-E2: Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands.</p> <p>INFLU-E3: When new technologies become available, they can bring about changes in the way people live and interact with one another.</p>	<p>INFLU-M1: All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.</p> <p>INFLU-M2: The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.</p> <p>INFLU-M3: Technology use varies over time and from region to region.</p>	<p>INFLU-H1: Modern technological systems, such as water, energy, transportation, and construction, all increase benefits to society and the environment.</p> <p>INFLU-H2: Engineers increase benefits to society and the environment through the design of products and systems.</p> <p>INFLU-H3: New technologies and products are not anticipated by society and the environment.</p> <p>INFLU-H4: Analysis of decisions about technology use is based on the benefits and risks to society and the environment.</p>
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Connections to the Nature of Science That Are Associated With the Practices

<p>VOM: Scientific Investigations Use a Variety of Methods</p>	<p>VOM-P1: Science investigations begin with a question.</p> <p>VOM-P2: Science uses different ways to study the world.</p>	<p>VOM-E1: Science methods are determined by questions.</p> <p>VOM-E2: Science investigations use a variety of methods, tools, and techniques.</p>	<p>VOM-M1: Science investigations use a variety of methods and tools to make measurements and observations.</p> <p>VOM-M2: Science investigations are guided by a set of values to ensure accuracy of measurements, observations, and objectivity of findings.</p> <p>VOM-M3: Science depends on evaluating proposed explanations.</p> <p>VOM-M4: Scientific values function as criteria in distinguishing between science and non-science.</p>	<p>VOM-H1: Science investigations use diverse methods and do not always use the same set of procedures to obtain data.</p> <p>VOM-H2: New technologies advance scientific knowledge.</p> <p>VOM-H3: Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings.</p> <p>VOM-H4: The discourse practices of science are organized around disciplinary domains that share exemplars for making decisions regarding the values, instruments, methods, models, and evidence to adopt and use.</p> <p>VOM-H5: Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge.</p>
<p>BEE: Science Knowledge Is Based on Empirical Evidence</p>	<p>BEE-P1: Scientists look for patterns and order when making observations about the world.</p>	<p>BEE-E1: Science findings are based on recognizing patterns.</p> <p>BEE-E2: Science uses tools and technologies to make accurate measurements and observations.</p>	<p>BEE-M1: Science knowledge is based upon logical and conceptual connections between evidence and explanations.</p> <p>BEE-M2: Science disciplines share common rules of obtaining and evaluating empirical evidence.</p>	<p>BEE-H1: Science knowledge is based on empirical evidence.</p> <p>BEE-H2: Science disciplines share common rules of evidence used to evaluate explanations about natural systems.</p> <p>BEE-H3: Science includes the process of coordinating patterns of evidence with current theory.</p> <p>BEE-H4: Science arguments are strengthened by multiple lines of evidence supporting a single explanation.</p>
<p>OTR: Scientific Knowledge Is Open to Revision in Light of New Evidence</p>	<p>OTR-P1: Science knowledge can change when new information is found.</p>	<p>OTR-E1: Science explanations can change based on new evidence.</p>	<p>OTR-M1: Scientific explanations are subject to revision and improvement in light of new evidence.</p> <p>OTR-M2: The certainty and durability of science findings varies.</p> <p>OTR-M3: Science findings are frequently revised and/or reinterpreted based on new evidence.</p>	<p>OTR-H1: Scientific explanations can be probabilistic.</p> <p>OTR-H2: Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.</p> <p>OTR-H3: Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.</p>

Use of Color



Science and Engineering Practices

Crosscutting Concepts

Disciplinary Core Ideas—Physical Science

Disciplinary Core Ideas—Life Science

Disciplinary Core Ideas—Earth and Space Science

**Disciplinary Core Ideas—Engineering, Technology,
and Applications of Science**

**Connections to Engineering, Technology, and
Applications of Science**

Connections to Nature of Science

5, 6, 7, & 8: Elements of the Three Dimensions for K–2, 3–5, 6–8, & 9–12



CHAPTER 5

Science and Engineering Practices for Grades K–2

AQDP: Ask Questions and Define Problems

Asking questions and defining problems in K–2 builds on prior experiences and progresses to asking questions and defining problems that can be tested.

AQDP-P1: Ask questions based on observations to find more information about the natural and/or designed world(s).

AQDP-P2: Ask and/or identify questions that can be answered by an investigation.

AQDP-P3: Define a simple problem to solve through the development of a tool.

MOD: Developing and Using Models

Modeling in K–2 builds on prior experiences and progresses to include using and developing physical replicas, dioramas, dramatization, or storyboard that represent concrete events or ideas.

MOD-P1: Distinguish between a model and the actual object, process, and/or events the model represents.

MOD-P2: Compare models to identify common features and differences.

MOD-P3: Develop and/or use models to represent amounts, relationships, and/or patterns in the natural and/or designed world(s).

MOD-P4: Develop a simple model to represent a proposed object, process, or event.

INV: Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in K–2 progresses to simple investigations, based on fair tests, which provide data to support explanations and models.

INV-P1: With guidance, plan and conduct an investigation in collaboration with peers.

INV-P2: Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.

INV-P3: Evaluate different ways of observing and/or measuring a phenomenon to determine which way can answer a question.

INV-P4: Make observations and/or measurements of a phenomenon to collect data that can be used to answer a question.

INV-P5: Make observations and/or measurements of a phenomenon to determine if a solution to a problem is effective.

INV-P6: Make predictions based on observations and/or measurements of a phenomenon.

DATA: Analyzing and Interpreting Data

Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and analyzing data to answer questions or test solutions to problems.

DATA-P1: Record information (observations, thoughts, and ideas).

DATA-P2: Use and share pictures, drawings, and/or writings of observations.

DATA-P3: Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems.

DATA-P4: Compare predicted and/or observed data to what occurred to determine if it works as intended.

DATA-P5: Analyze data from observations to determine if it works as intended.

MATH: Using Mathematics and Computational Thinking

Mathematical and computational thinking in K–2 builds on prior experience and progresses to using mathematical and computational thinking to describe the natural and designed world(s).

MATH-P1: Decide when to use qualitative vs. quantitative data.

MATH-P2: Use counting and numbers to identify and describe patterns in the natural and designed world(s).

MATH-P3: Describe, measure, and/or compare quantitative attributes of the data using simple graphs and/or tables.

MATH-P4: Use quantitative data to identify alternative solutions to a problem.

CHAPTER 5

Crosscutting Concepts for Grades K–2

PAT: Patterns

PAT-P1: Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

CE: Cause and Effect: Mechanism and Explanation

CE-P1: Simple tests can be designed to gather evidence to support or refute student ideas about causes.

CE-P2: Events have causes that can be described in terms of patterns.

SPQ: Scale, Proportion, and Quantity

SPQ-P1: Relative scales allow objects and events to be compared and described (e.g., bigger and smaller, hotter and colder, faster and slower).

SPQ-P2: Standard units are used to describe quantities.

SYS: Systems and System Models

SYS-P1: Objects and organisms can be described in terms of their parts.

SYS-P2: Systems in the natural and designed world(s) are made of parts that work together.

EM: Energy and Matter: Flows, Cycles, and Conservation

EM-P1: Objects may break into smaller pieces and be put together into larger pieces, or change shapes.

SF: Structure and Function

SF-P1: The shape and stability of structures of natural and designed objects are related to their function(s).

SC: Stability and Change

SC-P1: Some things stay the same while other things change.

SC-P2: Things may change over time.

Elements of the Three Dimensions for Grades K–2

Disciplinary Core Ideas: Physical Science for Grades K–2

PS1: Matter and Its Interactions

PS1.A: Structure and Properties of Matter
PS1.A-P1: Different kinds of matter exist and many of them can be either solid or liquid, depending on temperature. Matter can be described and classified by its observable properties.

PS1.A-P2: Different properties are suited to different purposes.

PS1.A-P3: A great variety of objects can be built up from a small set of pieces.

PS1.B: Chemical Reactions

PS1.B-P1: Heating or cooling a substance may cause changes that can be observed. Sometimes these changes are reversible, and sometimes they are not.

PS1.C: Nuclear Processes

No elements in this grade band

PS2: Motion and Stability: Forces and Interactions

PS2.A: Forces and Motion

PS2.A-P1: Pushes and pulls can have different strengths and directions.

PS2.A-P2: Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.

PS2.B: Types of Interactions

PS2.B-P1: When objects touch or collide, they push on one another and can change motion.

PS3: Energy

PS3.A: Definitions of Energy

No elements in this grade band

PS3.B: Conservation of Energy and Energy Transfer

PS3.B-P1: Sunlight warms Earth's surface.

PS3.C: Relationship Between Energy and Forces

PS3.C-P1: A bigger push or pull makes things speed up or slow down more quickly.

PS3.D: Energy in Chemical Processes and Everyday Life

No elements in this grade band

PS4: Waves and Their Applications in Technologies for Information Transfer

PS4.A: Wave Properties

PS4.A-P1: Sound can make matter vibrate, and vibrating matter can make sound.

PS4.B: Electromagnetic Radiation

PS4.B-P1: Objects can be seen only when light is available to illuminate them. Some objects give off their own light.

PS4.B-P2: Some materials allow light to pass through them, others allow only some light through, and still others block all the light and create a dark shadow on any surface beyond them, where the light cannot reach. Mirrors can be used to redirect a light beam. (Boundary: The idea that light travels from place to place is developed through experiences with light sources, mirrors, and shadows, but no attempt is made to discuss the speed of light.)

PS4.C: Information Technologies and Instrumentation

PS4.C-P1: People use a variety of devices to communicate (send and receive information) over long distances.

5, 6, 7, & 8: Elements of the Three Dimensions for K–2, 3–5, 6–8, & 9–12



CHAPTER 5

Disciplinary Core Ideas: Engineering, Technology, and Applications of Science for Grades K–2

ETS1: Engineering Design

ETS1.A: Defining and Delimiting an Engineering Problem

ETS1.A-P1: A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions.

ETS1.A-P2: Asking questions, making observations, and gathering information are helpful in thinking about problems.

ETS1.A-P3: Before beginning to design a solution, it is important to clearly understand the problem.

ETS1.B: Developing Possible Solutions

ETS1.B-P1: Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people.

ETS1.C: Optimizing the Design Solution

ETS1.C-P1: Because there is always more than one possible solution to a problem, it is useful to compare and test designs.

Connections to Engineering, Technology, and Applications of Science for Grades K–2

INFLU: Influence of Science, Engineering, and Technology on Society and the Natural World

INFLU-P1: People encounter questions about the natural world every day.

INTER-P2: Science and engineering involve the use of tools to observe and measure things.

INTER: Interdependence of Science, Engineering, and Technology

INFLU-P1: Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials.

INFLU-P2: Taking natural materials to make things impacts the environment.

INFLU-P3: People depend on various technologies in their lives; human life would be very different without technology.

Elements of the Three Dimensions for Grades K–2

Connections to the Nature of Science for Grades K–2

Connections to the Nature of Science That Are Associated With the Practices

VOM: Scientific Investigations Use a Variety of Methods

VOM-P1: Science investigations begin with a question.

VOM-P2: Science uses different ways to study the world.

BEE: Science Knowledge Is Based on Empirical Evidence

BEE-P1: Scientists look for patterns and order when making observations about the world.

OTR: Scientific Knowledge Is Open to Revision in Light of New Evidence

OTR-P1: Science knowledge can change when new information is found.

ENP: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

ENP-P1: Science uses drawings, sketches, and models as a way to communicate ideas.

ENP-P2: Science searches for cause and effect relationships to explain natural events.

Connections to the Nature of Science That Are Associated With the Crosscutting Concepts

WOK: Science Is a Way of Knowing

WOK-P1: Science knowledge helps us know about the world.

AOC: Scientific Knowledge Assumes an Order and Consistency in Natural Systems

AOC-P1: Science assumes natural events happen today as they happened in the past.

AOC-P2: Many events are repeated.

HE: Science Is a Human Endeavor

HE-P1: People have practiced science for a long time.

HE-P2: Men and women of diverse backgrounds are scientists and engineers.

AQAW: Science Addresses Questions About the Natural and Material World

AQAW-P1: Scientists study the natural and material world.

9: Performance Expectations



CHAPTER 9

List of All Performance Expectations With Clarification Statements and Assessment Boundaries

Kindergarten

K-PS2-1: Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object
Clarification Statement: Examples of pushes or pulls could include a string being pulled, a person pushing an object, and two objects colliding.
Assessment Boundary: relative strengths or directions of pushes or pulls should be assessed at the same time. Assessment does not include a string being pulled, a person pushing an object, and two objects colliding.

could include that it is usually cooler in the morning than in the afternoon and the number of sunny days versus cloudy days in different months.
Assessment Boundary: Assessment of quantitative observations limited to whole numbers and relative measures such as warmer/cooler.

K-PS2-2: Analyze data to identify patterns in the motion of an object with a push or a pull. A clarification statement is a solution could include move a certain distance, knock down other objects, include tools such as a ramp, and a structure that marble or ball to turn.
Assessment Boundary: limited to relative measures of motion.

K-PS2-3: Make observations and measurements to identify a simple design that reflects constraints or criteria.
Clarification Statement: include sand, soil, rocks, and other materials.
Assessment Boundary: limited to relative measures of motion.

K-PS3-1: Use tools and materials to build a structure that is strong enough to support a load and withstand applied forces.
Clarification Statement: include umbrellas, cars, and other structures.

K-PS3-2: Use tools and materials to build a structure that is strong enough to support a load and withstand applied forces.
Clarification Statement: include umbrellas, cars, and other structures.

K-LS1-1: Use observations and evidence to identify the conditions that describe life.
Clarification Statement: include that animals need food, water, and air to live, and that different kinds of animals have different needs for food, water, and air.

K-ESS2-1: Use and share information to describe the conditions that describe life.
Clarification Statement: observations could include such as sunny, cloudy, or rainy days in a given month.

Performance Expectations

The Connections Box

On the standards page, three connection boxes are located below the foundation boxes. The information in those boxes has been used to develop the list below. The list is designed to support a coherent vision of the standards by showing how the disciplinary core ideas (DCIs) that are related to a particular performance expectation (PE) connect to other DCIs and how the PEs in science connect to the *Common Core State Standards (CCSS)*. The connections are grouped into three sections:

Connections to other DCIs in this grade level

This column lists the DCIs that connect a given performance expectation to material covered at the same grade level but outside the presented sets of performance expectations. For example, both physical science and life science performance expectations contain core ideas related to photosynthesis and could be taught in relation to one another. Ideas within the same main DCI as the performance expectation (e.g., PS1.C for HS-PS1-1) are not included in the connection box, nor are ideas within the same topic arrangement as a performance expectation (e.g., HS.ESS2.B for HS-ESS1-6).

Articulation of DCIs across grade levels

This column lists DCIs that either (1) provide a foundation for student understanding of the core ideas in a given performance expectation (usually at prior grade levels) or (2) build on the foundation provided by the core ideas in this performance expectation (usually at subsequent grade levels).

Connections to the CCSS

The final two columns list pre-requisite or connected CCSS in English mathematics and language arts/literacy that align to given performance expectations. For example, performance expectations that require student use of exponential notation will align with the corresponding CCSS for mathematics. An effort has been made to ensure that the mathematical skills that students need for science were taught in a previous year where possible. Items appearing in italics are not pre-requisite to the successful accomplishment of a given performance expectation but are otherwise connected to it.

—Adapted from “How to Read the Next Generation Science Standards” (pp. xxii–xxvi) of the *NGSS*

PE Code	Conn. to Other DCIs in This Grade Level or Band	Articulations of DCIs Across Grade Levels or Bands	Conn. to CCSS in Mathematics	Conn. to CCSS in English Language Arts/Literacy
Kindergarten				
K-PS2-1		3.PS2.A, 3.PS2.B, 4.PS3.A	K.MD.A.1, K.MD.A.2, MP.2	W.K.7
K-PS2-2	K.ETS1.A, K.ETS1.B	2.ETS1.B, 3.PS2.A, 4.ETS1.A		RI.K.1, SL.K.3
K-PS3-1		1.PS4.B, 3.ESS2.D	K.MD.A.2	W.K.7
K-PS3-2	K.ETS1.A, K.ETS1.B	1.PS4.B, 2.ETS1.B, 4.ETS1.A	K.MD.A.2	W.K.7
K-LS1-1		1.LS1.A, 2.LS2.A, 3.LS2.C, 3.LS4.B, 3.LS1.C, 5.LS2.A	K.MD.A.2	W.K.7
K-ESS2-1		2.ESS2.A, 3.ESS2.D, 4.ESS2.A	MP.2, MP.4, K.CC.4, K.MD.A.1, K.MD.B.3	W.K.7
K-ESS2-2		4.ESS2.E, 5.ESS2.A		RI.K.1, W.K.1, W.K.2
K-ESS3-1		1.LS1.A, 5.LS2.A, 5.ESS2.A	MP.2, MP.4, K.CC	SL.K.5
K-ESS3-2	K.ETS1.A	2.ESS1.C, 3.ESS3.B, 4.ESS3.B	MP.4, K.CC	RI.K.1, SL.K.3
K-ESS3-3	K.ETS1.A	2.ETS1.B, 4.ESS3.A, 5.ESS3.C		W.K.2
Grade 1				
1.PS4-1		4.PS4.B		W.1.7, W.1.8, SL.1.1
1.PS4-2		2.PS1.A		W.1.2, W.1.7, W.1.8, SL.1.1
1.PS4-3		2.PS1.A		W.1.7, W.1.8, SL.1.1
1.PS4-4		K.ETS1.A, 2.ETS1.B, 4.PS4.C, 4.ETS1.A	MP.5, 1.MD.A.1, 1.MD.A.2	W.1.7
1.LS1-1		K.ETS1.A, 4.LS1.A, 4.LS1.D, 4.ETS1.A		W.1.7
1.LS2-2		3.LS2.D	1.NBT.B.3, 1.NBT.C.4, 1.NBT.C.5, 1.NBT.C.6	RI.1.1, RI.1.2, RI.1.10
1.LS3-1		3.LS3.A, 3.LS3.B	MP.2, MP.5, 1.MD.A.1	RI.1.1, W.1.7, W.1.8
1.ESS1-1				W.1.7, W.1.8
1.ESS1-2			MP.2, MP.4, MP.5, 1.OA.A.1, 1.MD.C.4	W.1.7, W.1.8

Three-Dimensional Elements Integrated Into the Performance Expectations

The chart below identifies the elements of all three dimensions that are integrated into each performance expectation. Codes for elements of the disciplinary core idea that are in *blue italic>* are considered to be secondary to the given performance expectation (PE). This simply means that the DCI element in question is affiliated with a different DCI than the PE. For example, the DCI element PS3.C-P1 is a secondary element to the PE K-PS2-1 because the DCI element is part of PS3: Energy but the PE is part of PS2: Motion and Stability: Forces and Interactions. DCI elements that are secondary to a particular PE are just as important as the DCI elements of the PE.

Performance Expectation	Science English Proficiency
Kindergarten	
K-PS2-1	INVA-F
K-PS2-2	DATA
K-PS3-1	INVA-F
K-PS3-2	CEDS
K-LS1-1	DATA
K-ESS2-1	DATA
K-ESS2-2	ARG-F
K-ESS3-1	MOD
K-ESS3-2	ACDP INFD
K-ESS3-3	INFO
Grade 1	
1.PS4-1	INVA-F
1.PS4-2	CEDS
1.PS4-3	INVA-F
1.PS4-4	CEDS
1.LS1-1	CEDS
1.LS1-2	INFO
1.LS3-1	CEDS
1.ESS1-1	DATA
1.ESS1-2	INVA-F
Grade 2	
2.PS1-1	INVA-F
2.PS1-2	DATA
2.PS1-3	CEDS
2.PS1-4	ARG-F
2.LS2-1	INVA-F
2.LS2-2	MOD
2.LS4-1	INVA-F
2.ESS1-1	CEDS
2.ESS2-1	CEDS
2.ESS2-2	MOD
2.ESS2-3	INFO

CHAPTER 9

Correspondence of Performance Expectations to Elements of the Disciplinary Core Ideas

This list of disciplinary core idea (DCI) elements indicates which performance expectations (PE) make use of the DCI element in question. If a PE is listed in *blue italic>*, it means that the DCI element is considered to be secondary to the PE, which simply means that the DCI element in question is affiliated with a different DCI than the PE. For example, the DCI element PS1.A-H3 is a secondary element to the PE HS-PS2-6 because the DCI element is part of PS1: Matter and Its Interactions but the PE is part of PS2: Motion and Stability: Forces and Interactions. DCI elements that are secondary to a particular PE are just as important as any other DCI elements of the PE.

Physical Science

PS1: Matter and Its Interactions

- PS1.A-P1: 2.PS1-1
- PS1.A-P2: 2.PS1-3, 2.PS1-2
- PS1.A-P3: 2.PS1-3
- PS1.A-E1: 5.PS1-1, 5.PS1-4
- PS1.A-E2: 5.PS1-2
- PS1.A-E3: 5.PS1-3
- PS1.A-M1: MS-PS1-1
- PS1.A-M2: MS-PS1-2, MS-PS1-3
- PS1.A-M3: MS-PS1-4
- PS1.A-M4: MS-PS1-4
- PS1.A-M5: MS-PS1-1
- PS1.A-M6: MS-PS1-4

- 2.PS1-1
- 2.PS1-2
- 2.PS1-3

- PS1.B-P1: 2.PS1-4
- PS1.B-E1: 5.PS1-2
- PS1.B-E2: MS-PS1-2, MS-PS1-3, MS-PS1-5
- PS1.B-M1: MS-PS1-5
- PS1.B-M2: MS-PS1-6
- PS1.B-M3: HS-PS1-4, HS-PS1-5
- PS1.B-H1: HS-PS1-6
- PS1.B-H2: HS-PS1-7
- PS1.B-H3: HS-PS1-8

- PS1.C-H1: HS-ESS1-5
- PS1.C-H2: HS-ESS1-6

PS2: Motion and Stability: Forces and Interactions

- PS2.A-P1: 3.PS2-1
- PS2.A-P2: 3.PS2-2
- PS2.A-E1: K.PS2-1, K.PS2-2
- PS2.A-E2: K.PS2-1, K.PS2-2
- PS2.A-M1: MS-PS2-1
- PS2.A-M2: MS-PS2-2
- PS2.A-M3: MS-PS2-2
- PS2.A-H1: HS-PS2-1

PS2: Motion and Stability: Forces and Interactions

- PS2.A-H2: HS-PS2-2
- PS2.A-H3: HS-PS2-2, HS-PS2-3
- PS2.B-P1: K-PS2-1
- PS2.B-E1: 3.PS2-1
- PS2.B-E2: 3.PS2-1, 3.PS2-3, 3.PS2-4
- PS2.B-E3: 5.PS2-1
- PS2.B-M1: MS-PS2-3
- PS2.B-M2: MS-PS2-4
- PS2.B-M3: MS-PS2-5
- PS2.B-H1: HS-PS2-4
- PS2.B-H2: HS-PS2-4, HS-PS2-5
- PS2.B-H3: HS-PS2-6, HS-PS1-1, HS-PS1-3

PS3: Energy

- PS3.A-E1: 4.PS3-1
- PS3.A-E2: 4.PS3-2, 4.PS3-3
- PS3.A-M1: MS-PS3-1
- PS3.A-M2: MS-PS3-2
- PS3.A-M3: MS-PS3-4
- PS3.A-M4: MS-PS3-3, MS-PS3-4, MS-PS1-4
- PS3.A-H1: HS-PS3-1, HS-PS3-2
- PS3.A-H2: HS-PS3-2, HS-PS3-3
- PS3.A-H3: HS-PS3-5
- PS3.A-H4: HS-PS3-2

- PS3.B-P1: K-PS3-1, K-PS3-2
- PS3.B-E1: 4.PS3-2, 4.PS3-3
- PS3.B-E2: 4.PS3-2
- PS3.B-E3: 4.PS3-2, 4.PS3-4
- PS3.B-M1: MS-PS3-3, MS-PS3-5
- PS3.B-M2: MS-PS3-4
- PS3.B-M3: MS-PS3-3
- PS3.B-H1: HS-PS3-2
- PS3.B-H2: HS-PS3-1, HS-PS3-4
- PS3.B-H3: HS-PS3-1
- PS3.B-H4: HS-PS3-4

- PS3.C-P1: K-PS2-1

PS4: Waves and Their Applications in Technologies for Information Transfer

- PS4.A-P1: 1.PS4-1
- PS4.A-E1: 4.PS4-1
- PS4.A-E2: 4.PS4-1
- PS4.A-M1: MS-PS4-1
- PS4.A-M2: MS-PS4-2
- PS4.A-H1: HS-PS4-3
- PS4.A-H2: HS-PS4-2
- PS4.A-H3: HS-ESS2-3

- PS4.B-P1: 1.PS4-2
- PS4.B-P2: 1.PS4-3
- PS4.B-E1: 4.PS4-2
- PS4.B-M1: MS-PS4-2
- PS4.B-M2: MS-PS4-2
- PS4.B-M3: MS-PS4-2
- PS4.B-M4: MS-PS4-2
- PS4.B-H1: HS-PS4-3
- PS4.B-H2: HS-PS4-4
- PS4.B-H3: HS-ESS1-2

- PS4.C-P1: 1.PS4-4
- PS4.C-E1: 4.PS4-3
- PS4.C-M1: MS-PS4-3
- PS4.C-H1: HS-PS4-5

The NSTA

Retaining Features from the Original



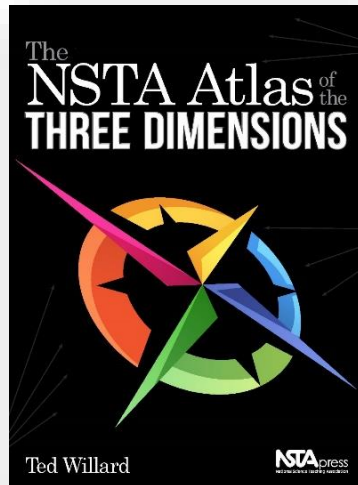
This new version of the Quick-Reference Guide still contains the most useful features of the original, including:

- Descriptions of the science and engineering practices and the crosscutting concepts from the *Framework*
- K–12 progressions of the elements of all three dimensions, as well as the connections to the nature of science and the connections to engineering
- Chapters devoted to elements of the three dimensions in each grade span: K–2, 3–5, 6–8, and 9–12
- Tools to help make sense of the standards such as an overview of the three dimensions, a guide to inside the standards box, and a Venn diagram of practices in science, mathematics, and English language arts

New Features: Element Codes



- A unique code for every element (based on the codes in the NSTA Atlas of the Three Dimensions) that makes it much easier to reference a particular element.



Element Codes

Topic Code

Grade Band

- P = Primary (K–2)
- E = Elementary (3–5)
- M = Middle School (6–8)
- H = High School (9–12)

PS1.A-M1

Element Number

Indicates whether it is the 1st, 2nd, 3rd, etc. element for the topic in that grade band

New Features: PEs in One Chapter



- Information about the performance expectations (PEs) contained in their own chapter so that they are available to educators from states that have adopted the NGSS or that have standards with many of the same PEs as the NGSS.
- A list of performance expectations that includes the text of the clarification statements and assessment boundaries.
- Tables that make clear which elements of the three dimensions were integrated together for every performance expectation and how science standards are connected to standards in mathematics and English language arts.
- Chapters that focus on elements of the three dimensions in a particular grade span with lists of the disciplinary core ideas in that grade span that are easy to read.

New Features: New Tools



New tools for working with standards such as

- questions for unpacking standards,
- a rubric for evaluating three-dimensional lessons and units,
- information about using phenomena in three-dimensional lessons and units, and a
- diagram describing how modeling, explaining, and arguing connect phenomena and science ideas.

Questions?



Chapter 3

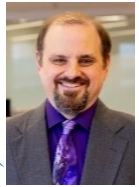
Tools for Working With Standards

Ch. 3: Tools for Working With Standards



1. Overview of the Three Dimensions
2. Inside the Standards Box
3. Guiding Questions for Unpacking the Standards
4. Practices in Science, Mathematics, and English Language Arts
5. Venn Diagram of the Practices in Science, Mathematics, and English Language Arts
6. Standards Organized by Topics
7. Standards Organized by Disciplinary Core Ideas
8. A New Vision for Science Education From *A Framework for K–12 Science Education*
9. Using Phenomena in Three-Dimensional Lessons and Units
10. How Modeling, Explaining, and Arguing Connect Phenomena and Science Ideas
11. A Standards-Based Process for Developing Lessons and Units
12. Rubric for Evaluating Three-Dimensional Lessons and Units
13. List of Topic Codes and Element Code Key

Overview of the Three Dimensions



Overview of the Three Dimensions

Scientific and Engineering Practices

Asking Questions and Defining Problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.

Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify the ideas of others.

Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.

Modeling tools are used to develop questions, predictions and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

Planning and Carrying Out Investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.

Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.

Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

Using Mathematics and Computational Thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.

Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. Statistical methods are frequently used to identify significant patterns and establish causal relationships.

Constructing, Using, and Refining Models

The goal is to represent the world and great ideas. The goal on science from a practical cost, safe depends

In science identify problem competing Scientist testing a and using

Commun diagrams extended informat designs.

Crosscutting Concepts

Patterns

Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Cause and Effect: Mechanism and Explanation

Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Scale, Proportion, and Quantity

In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

Systems and System Models

Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

Energy and Matter: Flows, Cycles, and Conservation

Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Structure and Function

The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

Stability and Change

For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Disciplinary Core Ideas

Physical Science	Life Science	Earth and Space Science	Engineering, Technology, and Applications of Science
<p>PS1: Matter and Its Interactions</p> <p>PS1.A: Structure and Properties of Matter</p> <p>PS1.B: Chemical Reactions</p> <p>PS1.C: Nuclear Processes</p> <p>PS2: Motion and Stability: Forces and Interactions</p> <p>PS2.A: Forces and Motion</p> <p>PS2.B: Types of Interactions</p> <p>PS2.C: Stability and Instability in Physical Systems</p> <p>PS3: Energy</p> <p>PS3.A: Definitions of Energy</p> <p>PS3.B: Conservation of Energy and Energy Transfer</p> <p>PS3.C: Relationship Between Energy and Forces</p> <p>PS3.D: Energy in Chemical Processes and Everyday Life</p> <p>PS4: Waves and Their Applications in Technologies for Information Transfer</p> <p>PS4.A: Wave Properties</p> <p>PS4.B: Electromagnetic Radiation</p> <p>PS4.C: Information Technologies and Instrumentation</p>	<p>LS1: From Molecules to Organisms: Structures and Processes</p> <p>LS1.A: Structure and Function</p> <p>LS1.B: Growth and Development of Organisms</p> <p>LS1.C: Organization for Matter and Energy Flow in Organisms</p> <p>LS1.D: Information Processing</p> <p>LS2: Ecosystems: Interactions, Energy, and Dynamics</p> <p>LS2.A: Interdependent Relationships in Ecosystems</p> <p>LS2.B: Cycles of Matter and Energy Transfer in Ecosystems</p> <p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience</p> <p>LS2.D: Social Interactions and Group Behavior</p> <p>LS3: Heredity: Inheritance and Variation of Traits</p> <p>LS3.A: Inheritance of Traits</p> <p>LS3.B: Variation of Traits</p> <p>LS4: Biological Evolution: Unity and Diversity</p> <p>LS4.A: Evidence of Common Ancestry and Diversity</p> <p>LS4.B: Natural Selection</p> <p>LS4.C: Adaptation</p> <p>LS4.D: Biodiversity and Humans</p>	<p>ESS1: Earth's Place in the Universe</p> <p>ESS1.A: The Universe and Its Stars</p> <p>ESS1.B: Earth and the Solar System</p> <p>ESS1.C: The History of Planet Earth</p> <p>ESS2: Earth's Systems</p> <p>ESS2.A: Earth Materials and Systems</p> <p>ESS2.B: Plate Tectonics and Large-Scale System Interactions</p> <p>ESS2.C: The Roles of Water in Earth's Surface Processes</p> <p>ESS2.D: Weather and Climate</p> <p>ESS2.E: Biogeology</p> <p>ESS3: Earth and Human Activity</p> <p>ESS3.A: Natural Resources</p> <p>ESS3.B: Natural Hazards</p> <p>ESS3.C: Human Impacts on Earth Systems</p> <p>ESS3.D: Global Climate Change</p>	<p>ETS1: Engineering Design</p> <p>ETS1.A: Defining and Delimiting an Engineering Problem</p> <p>ETS1.B: Developing Possible Solutions</p> <p>ETS1.C: Optimizing the Design Solution</p>

Inside the Standards Box



Inside the Standards Box

What Is Assessed

A collection of several performance expectations describing what students should be able to do at the end of instruction

Foundation Box

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

Connection Box

Places elsewhere within these standards (or in mathematics or ELA standards) that are connected to the performance expectations on this page

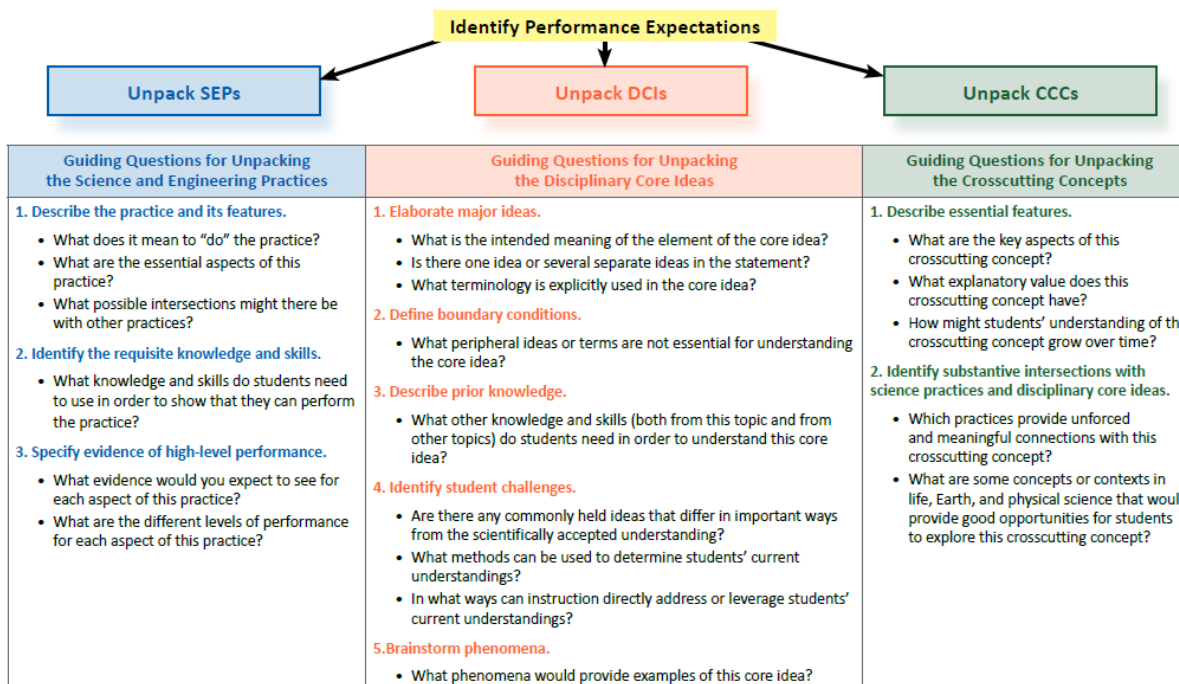
MS-LS2 Ecosystems: Interactions, Energy, and Dynamics		
Students who demonstrate understanding can:		
MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. [Clarification Statement: Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems, and on defining the boundaries of the system.] [Assessment Boundary: Assessment does not include the use of chemical reactions to describe the processes.]	Title The title for a set of performance expectations. It is not necessarily unique and may be reused at several different grade levels.	
MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.]	Performance Expectations A statement that combines practices, core ideas, and crosscutting concepts together to describe how students can show what they have learned.	
MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services. [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]	Clarification Statement A statement that supplies examples or additional clarification to the performance expectation.	
The performance expectations above were developed using the following elements from the <i>Framework for K–12 Science Education</i> :		
<p>Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and refining models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to describe phenomena. (MS-LS2-3)</p> <p>Engaging in Argument from Evidence Practices in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). • Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-LS2-4) • Evaluate competing design solutions based on partly developed and agreed upon design criteria. (MS-LS2-5)</p> <p>Connections to Nature of Science Scientific Knowledge is Based on Empirical Evidence • Science disciplines share common uses of analyzing and evaluating empirical evidence. (MS-LS2-4)</p>	<p>Disciplinary Core Ideas LS2.B: Cycles of Matter and Energy Transfer in Ecosystems • Most cells are models that demonstrate how matter and energy is transferred between organisms, cells, and structures at the three scales: interact within an ecosystem, transfer of matter into and out of the system, and matter and energy flow into and out of the system. • Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. (MS-LS2-3)</p> <p>LS2.C: Ecosystem Dynamics, Functioning, and Resilience • Ecosystems are dynamic in nature; their characteristics can vary over time. Disturbances to any physical or biological component of an ecosystem can lead to shifts in all populations. (MS-LS2-4) • Biodiversity describes the variety of species found in Earth's terrestrial and aquatic ecosystems. The complexity or integrity of an ecosystem's biodiversity is often used as a measure of its health. (MS-LS2-5)</p> <p>LS2.D: Biodiversity and Humans • Changes in biodiversity can influence human resources, such as fisheries, and resources, as well as ecosystem services that humans rely on, such as water purification and recycling. (MS-LS2-5)</p> <p>ESS1.B: Developing Possible Solutions • There are often multiple, competing, and/or conflicting solutions with respect to how well they meet the criteria and constraints of a problem. (MS-LS2-5)</p>	<p>Crosscutting Concepts Energy and Matter • The transfer of energy can be tracked as energy flow through a natural system. (MS-LS2-3)</p> <p>Stability and Change • Small changes in one part of a system might cause big changes in another part. (MS-LS2-5)</p> <p>Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World • The use of technologies and any limitations on their use are shown by individual or social needs, desires, and values; by the findings of scientific research; and by differences in both faiths (e.g., climate, natural resources, and economic conditions) and over time. (MS-LS2-5)</p> <p>Connections to Nature of Science Scientific Knowledge Assesses an Order and Consistency in Natural Systems • Science assumes that topics and events in natural systems occur in consistent patterns that are understandable through measurement and observation. (MS-LS2-3)</p> <p>Science Addresses Questions About the Natural and Human-Made World • Scientific knowledge can describe the consistency of natural systems, but researchers investigate the questions that society raises. (MS-LS2-5)</p>
<p>Connections to other DCIs in the grade band: MS.PS1.B (MS-LS2-3), MS.LS4.C (MS-LS2-3), MS.LS4.D (MS-LS2-3), MS.ESS2.A (MS-LS2-3), MS.ESS2.C (MS-LS2-3), MS.ESS2.D (MS-LS2-3), MS.ESS3.A (MS-LS2-3), MS.ESS3.B (MS-LS2-3), MS.ESS3.C (MS-LS2-3), MS.ESS3.D (MS-LS2-3), MS.ESS4.A (MS-LS2-3), MS.ESS4.B (MS-LS2-3), MS.ESS4.C (MS-LS2-3), MS.ESS4.D (MS-LS2-3), MS.ESS4.E (MS-LS2-3), MS.ESS4.F (MS-LS2-3), MS.ESS4.G (MS-LS2-3), MS.ESS4.H (MS-LS2-3), MS.ESS4.I (MS-LS2-3), MS.ESS4.J (MS-LS2-3), MS.ESS4.K (MS-LS2-3), MS.ESS4.L (MS-LS2-3), MS.ESS4.M (MS-LS2-3), MS.ESS4.N (MS-LS2-3), MS.ESS4.O (MS-LS2-3), MS.ESS4.P (MS-LS2-3), MS.ESS4.Q (MS-LS2-3), MS.ESS4.R (MS-LS2-3), MS.ESS4.S (MS-LS2-3), MS.ESS4.T (MS-LS2-3), MS.ESS4.U (MS-LS2-3), MS.ESS4.V (MS-LS2-3), MS.ESS4.W (MS-LS2-3), MS.ESS4.X (MS-LS2-3), MS.ESS4.Y (MS-LS2-3), MS.ESS4.Z (MS-LS2-3), MS.ESS5.A (MS-LS2-3), MS.ESS5.B (MS-LS2-3), MS.ESS5.C (MS-LS2-3), MS.ESS5.D (MS-LS2-3), MS.ESS5.E (MS-LS2-3), MS.ESS5.F (MS-LS2-3), MS.ESS5.G (MS-LS2-3), MS.ESS5.H 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Guiding Questions for Unpacking the Standards



The NSTA Quick-Reference Guide to the Three Dimensions

Guiding Questions for Unpacking the Standards



From: The NSTA Atlas of the Three Dimensions (Willard, 2020) based on procedures described in Creating and Using Instructionally Supportive Assessments in NGSS Classrooms (Harris, Krajcik, and Pellegrino, forthcoming).

Guiding Questions for Unpacking the Science and Engineering Practices



1. Describe the practice and its features.

- What does it mean to “do” the practice?
- What are the essential aspects of this practice?
- What possible intersections might there be with other practices?

2. Identify the requisite knowledge and skills.

- What knowledge and skills do students need to use in order to show that they can perform the practice?

3. Specify evidence of high-level performance.

- What evidence would you expect to see for each aspect of this practice?
- What are the different levels of performance for each aspect of this practice?

Venn Diagram of the Practices in Science Mathematics and English Language Arts

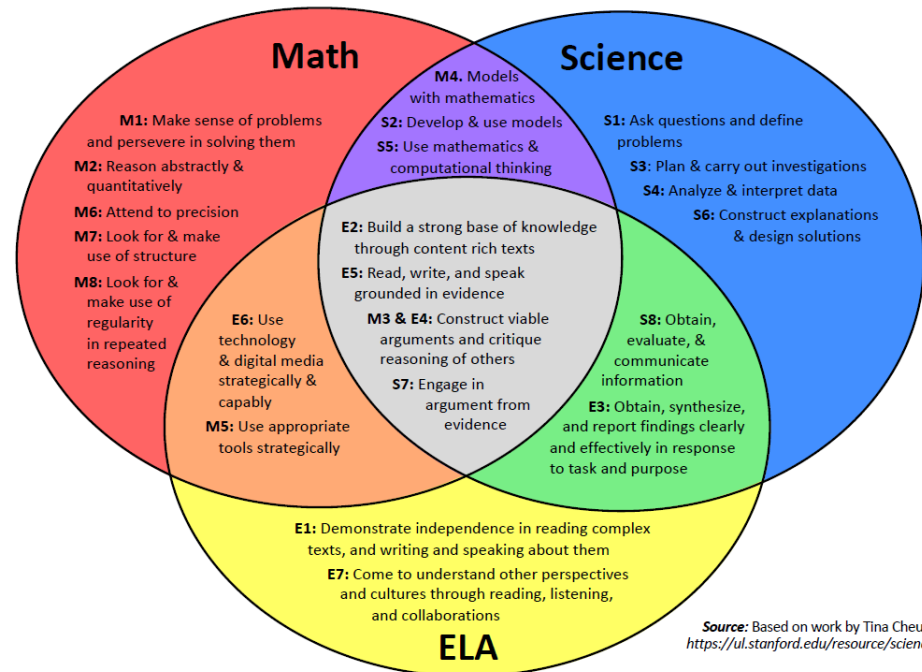


Practices in Science, Mathematics, and English Language Arts

Math	Science	English Language Arts*
M1. Make sense of problems and persevere in solving them.	S1. Asking questions (for science) and defining problems (for engineering).	E1. They demonstrate independence.
M2. Reason abstractly and quantitatively.	S2. Developing and using models	
M3. Construct viable arguments and critique the reasoning of others.	S3. Planning and carrying out investigations.	
M4. Model with mathematics.	S4. Analyzing and interpreting data	
M5. Use appropriate tools strategically.	S5. Using mathematics, information and computer technology to enhance understanding and computational thinking.	
M6. Attend to precision.	S6. Constructing explanations (for science) and designing solutions (for engineering).	
M7. Look for and make use of structure.	S7. Engaging in argument from evidence.	
M8. Look for and express regularity in repeated reasoning.	S8. Obtaining, evaluating, and communicating information	

* In English Language Arts, the term "student capacities" is used rather than the term "practices".

Venn Diagram of the Practices in Science, Mathematics, and English Language Arts



The NSTA Quick-Reference Guide to the Three Dimensions

Source: Based on work by Tina Cheuk, <https://ul.stanford.edu/resource/science>

Standards Organized by Topics and by Disciplinary Core Ideas



Standards Organized by Topics

	Physical Science	Life Science	Earth & Space Science	Engineering
Elementary School	K. Forces and Interactions: Pushes and Pulls	K. Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment	K. Weather and Climate	
	1. Waves: Light and Sound	1. Structure and Function		
	2. Structure and Properties of Matter	2. Interdependent Relationships		
	3. Forces and Interactions	3. Interdependent Relationships 3. Inheritance and Variation of Traits		
	4. Energy 4. Waves: Waves and Information	4. Structure and Function		
5. Structure and Properties of Matter	5. Matter and Energy in Organisms			
Middle School	MS. Structure and Properties of Matter MS. Chemical Reactions MS. Forces and Interactions MS. Energy MS. Waves and Electromagnetic Radiation	MS. Structure and Function MS. Matter and Energy in Organisms MS. Interdependent Relationships MS. Natural Selection and Adaptation MS. Growth, Development, and Evolution of Organisms		
	HS. Structure and Properties of Matter HS. Chemical Reactions HS. Forces and Interactions HS. Energy HS. Waves and Electromagnetic Radiation	HS. Structure and Function HS. Inheritance and Variation of Traits HS. Matter and Energy in Organisms HS. Interdependent Relationships HS. Natural Selection and Evolution of Organisms		

Standards Organized by Disciplinary Core Ideas

	Physical Science	Life Science	Earth & Space Science	Engineering
Elementary School	K. PS2 Motion and Stability: Forces and Interactions K. PS3 Energy	K-LS1 From Molecules to Organisms: Structures and Processes	K-ESS2 Earth's Systems K-ESS3 Earth and Human Activity	
	1-PS4 Waves and Their Applications in Technologies for Information Transfer	1-LS1 From Molecules to Organisms: Structures and Processes 1-LS3 Heredity: Inheritance and Variation of Traits	1-ESS1 Earth's Place in the Universe	K-2-ETS1 Engineering Design
	2-PS1 Matter and Its Interactions	2-LS2 Ecosystems: Interactions, Energy, and Dynamics 2-LS4 Biological Evolution: Unity and Diversity	2-ESS1 Earth's Place in the Universe 2-ESS2 Earth's Systems	
	3-PS2 Motion and Stability: Forces and Interactions	3-LS1 From Molecules to Organisms: Structures and Processes 3-LS2 Ecosystems: Interactions, Energy, and Dynamics 3-LS3 Heredity: Inheritance and Variation of Traits 3-LS4 Biological Evolution: Unity and Diversity	3-ESS2 Earth's Systems 3-ESS3 Earth and Human Activity	
	4-PS3 Energy 4-PS4 Waves and Their Applications in Technologies for Information Transfer	4-LS1 From Molecules to Organisms: Structures and Processes	4-ESS1 Earth's Place in the Universe 4-ESS2 Earth's Systems 4-ESS3 Earth and Human Activity	3-5-ETS1 Engineering Design
5-PS1 Matter and Its Interactions 5-PS2 Motion and Stability: Forces and Interactions 5-PS3 Energy	5-LS1 From Molecules to Organisms: Structures and Processes 5-LS2 Ecosystems: Interactions, Energy, and Dynamics	5-ESS1 Earth's Place in the Universe 5-ESS2 Earth's Systems 5-ESS3 Earth and Human Activity		
Middle School	MS-PS1 Matter and Its Interactions MS-PS2 Motion and Stability: Forces and Interactions MS-PS3 Energy HS-PS4 Waves and Their Applications in Technologies for Information Transfer	MS-LS1 From Molecules to Organisms: Structures and Processes MS-LS2 Ecosystems: Interactions, Energy, and Dynamics MS-LS3 Heredity: Inheritance and Variation of Traits MS-LS4 Biological Evolution: Unity and Diversity	MS-ESS1 Earth's Place in the Universe MS-ESS2 Earth's Systems MS-ESS3 Earth and Human Activity	MS-ETS1 Engineering Design
	HS-PS1 Matter and Its Interactions HS-PS2 Motion and Stability: Forces and Interactions HS-PS3 Energy HS-PS4 Waves and Their Applications in Technologies for Information Transfer	HS-LS1 From Molecules to Organisms: Structures and Processes HS-LS2 Ecosystems: Interactions, Energy, and Dynamics HS-LS3 Heredity: Inheritance and Variation of Traits HS-LS4 Biological Evolution: Unity and Diversity	HS-ESS1 Earth's Place in the Universe HS-ESS2 Earth's Systems HS-ESS3 Earth and Human Activity	HS-ETS1 Engineering Design

A New Vision for Science Education and Using Phenomena in Three-Dimensional Lessons & Units



CHAPTER 3

A New Vision for Science Education From *A Framework for K–12 Science Education**

Overarching Goal: To ensure that by the end of 12th grade, *all* students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, technology.

Implications of the Vision**

SCIENCE EDUCATION WILL INVOLVE LESS:	SCIENCE EDUCATION WILL INVOLVE MORE:
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning.
Learning of ideas disconnected from questions about phenomena	Systems thinking and modeling to explain phenomena and to give a context for the ideas to be learned
Teachers providing information to the whole class	Students conducting investigations, solving problems, and engaging in discussions with teachers' guidance
Teachers posing questions with only one right answer	Students discussing open-ended questions that focus on the strength of the evidence used to generate claims
Students reading textbooks and answering questions at the end of the chapter	Students reading multiple sources, including science-related magazine and journal articles and web-based resources; students developing summaries of information.
Pre-planned outcome for "cookbook" laboratories or hands-on activities	Multiple investigations driven by students' questions with a range of possible outcomes that collectively lead to a deep understanding of established core scientific ideas
Worksheets	Student writing of journals, reports, posters, and media presentations that explain and argue
Oversimplification of activities for students who are perceived to be less able to do science and engineering	Provision of supports so that all students can engage in sophisticated science and engineering practices

* National Research Council. (2012). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. (p. 1). Washington, DC: The National Academies Press. <https://nsp.nationalacademies.org/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts>

** Source: National Research Council. (2015). *Guide to Implementing the Next Generation Science Standards* (pp. 8–9). Washington, DC: National Academies Press. <http://www.nsp.edu/catalog/18902/guide-to-implementing-the-next-generation-science-standards>

Using Phenomena in Three-Dimensional Lessons and Units*

WHAT ARE PHENOMENA IN SCIENCE AND ENGINEERING?

- Natural phenomena are observable events that occur in the universe and that we can use our science knowledge to explain or predict. The goal of building knowledge in science is to develop general ideas, based on evidence, that can explain and predict phenomena.
- Engineering involves designing solutions to problems that arise from phenomena, and using explanations of phenomena to design solutions.
- In this way, phenomena are the context for the work of both the scientist and the engineer.

WHY ARE PHENOMENA SUCH A BIG DEAL?

- Despite their centrality in science and engineering, phenomena have traditionally been a missing piece in science education, which too often has focused on teaching general knowledge that students can have difficulty applying to real world contexts.
- Anchoring learning in explaining phenomena supports student agency for wanting to build science and engineering knowledge. Students are able to identify an answer to "why do I need to learn this?" before they even know what the "this" is. In contrast, students might not understand the importance of learning science ideas that teachers and curriculum designers know are important but that are unconnected from phenomena.
- By centering science education on phenomena that students are motivated to explain, the focus of learning shifts from learning about a topic to figuring out why or how something happens. For example, instead of simply learning about the topics of photosynthesis and mitosis, students are engaged in building evidence-based explanatory ideas that help them figure out how a tree grows.
- Explaining phenomena and designing solutions to problems allow students to build general science ideas in the context of their application to understanding phenomena in the real world, leading to deeper and more transferable knowledge.
- Students who come to see how science ideas can help explain and model phenomena related to compelling real world situations learn to appreciate the social relevance of science. They get interested in and identify with science as a way of understanding and improving real world contexts. Focusing investigations on compelling phenomena can help sustain students' science learning.

HOW ARE PHENOMENA RELATED TO THREE-DIMENSIONAL LEARNING?

- *The Next Generation Science Standards (NGSS)* and other standards based on *A Framework for K–12 Science Education* focus on helping students use science to make sense of phenomena in the natural and designed world, and use engineering to solve problems.
- Learning to explain phenomena and solve problems is the central reason students engage in the three dimensions. Students explain phenomena by developing and applying the disciplinary core ideas (DCIs) and crosscutting concepts (CCCs) through use of the science and engineering practices (SEPs).
- Phenomena-centered classrooms also give students and teachers a context in which to monitor ongoing progress toward understanding all three dimensions. As students are working toward being able to explain phenomena, three-dimensional formative assessment becomes more easily embedded and coherent throughout instruction.

* Based on *Using Phenomena in NGSS-Designed Lessons and Units* published in 2016 by Achieve, nextgenstorylines.org, and STEM Teaching Tools, but references to NGSS have been generalized to accommodate other standards based on *A Framework for K–12 Science Education*. The original version can be found here: <https://www.nextgenscience.org/resources/phenomena>.

Guides on Modeling, Explaining, and Arguing and A Standards-Based Process for Developing Lessons & Units



How Modeling, Explaining, and Arguing Connect Phenomena and Science Ideas

Notes

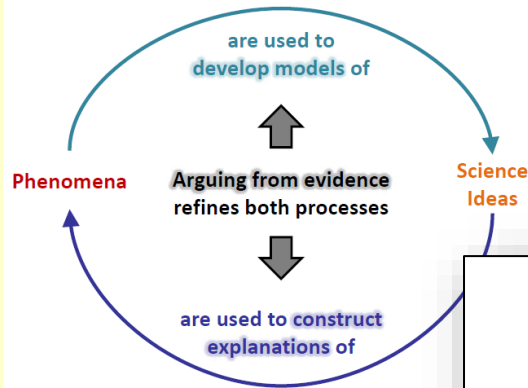
The diagram describes the relationship between phenomena, science ideas, and several of the science and engineering practices that are often absent or underused in traditional instruction.

Scientists (and students) study phenomena and they use the evidence gathered from experiencing phenomena to develop models of scientific ideas.

They can then use those scientific ideas to construct explanations of the original phenomena as well as new phenomena they encounter.

When engaged in developing models and constructing explanations, scientists and students often need to engage in arguing from evidence as a way of refining their models and/or their explanations.

There is often confusion about the difference between constructing explanations and engaging in argument from evidence. The diagram can help distinguish between the two and it also shows how developing models is distinct from both. It also can help illustrate the role of phenomena in three-dimensional, phenomenon-based teaching and learning.



A Standards-Based Process for Developing Lessons and Units

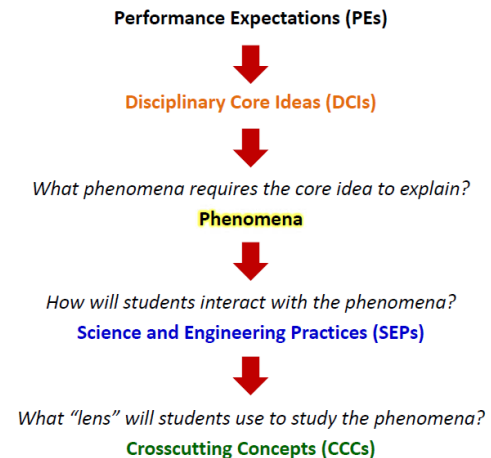
Notes

This diagram illustrates a method for educators to identify instructionally productive phenomena and grade-appropriate elements of the practices and crosscutting concepts that support students in learning targeted core ideas.

Educators often start with a need to target a specific performance expectation (PE), but instruction does not need to focus on the particular combination of practice, core idea, and crosscutting concept that are used in the PE. Instead, a set of SEPs, DCIs, and CCCs that fit together coherently in the investigation of a phenomenon should be selected.

This set of questions involve using the core idea to select a phenomenon (or several phenomena) and then thinking about how students will explain how or why the phenomenon occur in order to select a practice and crosscutting concept.

Of course, this set of questions is only a small part of the process of developing a lesson or unit and often the initial choices will need to be reevaluated at different points and changes may need to be made. However, the questions have proven useful for helping educators identify the elements of the three dimensions to use in instruction.



Rubric for Evaluating Three-Dimensional Lessons and Units



Rubric for Evaluating Three-Dimensional Lessons and Units*

Lessons and units designed for three-dimensional teaching and learning include clear and compelling evidence of the following:

I. 3D Design	II. Instructional Supports	III. Monitoring Student Progress
<p><i>The lesson/unit is designed so students make sense of phenomena and/or design solutions to problems by engaging in student performances that integrate the three dimensions.</i></p> <p>A. Explaining Phenomena/Designing Solutions: Making sense of phenomena and/or designing solutions to a problem drive student learning.</p> <ol style="list-style-type: none"> Student questions and prior experiences related to the phenomenon or problem motivate sense-making and/or problem solving. The focus of the lesson is to support students in making sense of phenomena and/or designing solutions to problems. When engineering is a learning focus, it is integrated with developing disciplinary core ideas from physical, life, and/or earth and space sciences. <p>B. Three Dimensions: Builds understanding of multiple grade-appropriate elements of the science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCCs) that are deliberately selected to aid student sense-making of phenomena and/or designing of solutions.</p> <ol style="list-style-type: none"> Provides opportunities to develop and use specific elements of the SEP(s). Provides opportunities to develop and use specific elements of the DCI(s). Provides opportunities to develop and use specific elements of the CCC(s). <p>C. Integrating the Three Dimensions: Student sense-making of phenomena and/or designing of solutions requires student performances that integrate elements of the SEPs, CCCs, and DCIs.</p>	<p>A. Relevance and Authenticity: Engages students in authentic and meaningful scenarios that reflect the practice of science and engineering as experienced in the real world.</p> <ol style="list-style-type: none"> Students experience phenomena or design problems as directly as possible (firsthand or through media representations). Includes suggestions for how to connect instruction to the students' home, neighborhood, community and/or culture as appropriate. Provides opportunities for students to connect their explanation of a phenomenon and/or their design solution to a problem to questions from their own experience. <p>B. Student Ideas: Provides opportunities for students to express, clarify, justify, interpret, and represent their ideas and to respond to peer and teacher feedback orally and/or in written form as appropriate.</p> <p>C. Building Progressions: Identifies and builds on students' prior learning in all three dimensions, including providing the following support to teachers:</p> <ol style="list-style-type: none"> Explicitly identifying prior student learning expected for all three dimensions Clearly explaining how the prior learning will be built upon <p>D. Scientific Accuracy: Uses scientifically accurate and grade-appropriate scientific information, phenomena, and representations to support students' three-dimensional learning.</p> <p>E. Differentiated Instruction: Provides guidance for teachers to support differentiated instruction by including:</p> <ol style="list-style-type: none"> Supportive ways to access instruction, including appropriate linguistic, visual, and kinesthetic engagement opportunities that are essential for effective science and engineering learning and particularly beneficial for multilingual learners and students with disabilities. Extra support (e.g., phenomena, representations, tasks) for students who are struggling to meet the targeted expectations. Extensions for students with high interest or who have already met the performance expectations to develop deeper understanding of the practices, disciplinary core ideas, and crosscutting concepts. 	<p><i>The lesson/unit supports monitoring student progress in all three dimensions as students make sense of phenomena and/or design solutions to problems.</i></p> <p>A. Monitoring 3D Student Performances: Elicits direct, observable evidence of three-dimensional learning; students are using practices with core ideas and crosscutting concepts to make sense of phenomena and/or to design solutions.</p> <p>B. Formative: Embeds formative assessment processes throughout that evaluate student learning to inform instruction.</p> <p>C. Scoring Guidance: Includes aligned rubrics and scoring guidelines that provide guidance for interpreting student performance along the three dimensions to support teachers in (a) planning instruction and (b) providing ongoing feedback to students.</p> <p>D. Unbiased Tasks/Items: Assesses student proficiency using methods, vocabulary, representations, and examples that are accessible and unbiased for all students.</p>

II. Instructional Supports	III. Monitoring Student Progress
<p>A. Supports teachers in facilitating student engagement across lessons (e.g., helping students connect related concepts across lessons, etc.).</p> <p>B. Supports student sense-making and/or problem solving in all three dimensions.</p> <p>C. Provides supports to help students who are increasingly responsible for designing solutions to problems.</p>	<p>A. Coherent Assessment system: Includes pre-, formative, summative, and self-assessment measures that assess three-dimensional learning.</p> <p>B. Opportunity to learn: Provides multiple opportunities for students to demonstrate performance of practices connected with their understanding of disciplinary core ideas and crosscutting concepts and receive feedback.</p>

* This rubric is based on Version 5.1 of the Educators Evaluating the Quality of Instructional Products (EQUIP) Rubric which was published in April 2021. The criteria in this rubric are identical to the EQUIP Rubric, but references to NGSS have been generalized to accommodate other standards based on the Framework. The complete EQUIP also contains scoring guidelines and instructions for use. It can be found here: <https://www.nextgenscience.org/resources/equip-rubric-science>

The rubric provides criteria by which to measure the alignment and overall quality of lessons and units with respect to the Next Generation Science Standards (NGSS) and other standards based on A Framework for K-12 Science Education. The purposes of the rubric and review process are to: (1) review existing lessons and units to determine what revisions are needed; (2) provide constructive criterion-based feedback and suggestions for improvement to developers; (3) identify exemplars and/or models for teachers' use within and across states; and (4) to inform the development of new lessons and units. To effectively apply this rubric, users should have a thorough understanding of the National Research Council's A Framework for K-12 Science Education and the Next Generation Science Standards, including the shifts described in Appendix A.

The power of the rubric is in the feedback and suggestions for improvement it provides curriculum developers and the productive conversations in which educators engage while evaluating materials using the quality review process. For curriculum developers, the rubric and review process provide evidence of the quality and the degree to which the lesson or unit is designed for the NGSS. Additionally, the rubric and review process generate suggestions for improvement on how materials can be further improved and better designed to match up with the vision of the Framework and the NGSS.

List of Topic Codes and Element Code Key



List of Topic Codes and Element Code Key

Science and Engineering Practices

- AQDP: Ask Questions and Define Problems
- MOD: Developing and Using Models
- INV: Planning and Carrying Out Investigations
- DATA: Analyzing Data
- MATH: Using Mathematics and Computational Thinking
- CEDS: Constructing Explanations and Designing Solutions
- ARG: Engaging in Argument From Evidence
- INFO: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts

- PAT: Patterns
- CE: Cause and Effect: Mechanism and Explanation
- SPQ: Scale, Proportion, and Quantity
- SYS: Systems and Systems Models
- EM: Energy and Matter: Flow, Cycles, and Conservation
- SF: Structure and Function
- SC: Stability and Change

Disciplinary Core Ideas in Physical Science

- PS1: Matter and Its Interactions
 - PS1.A: Structure and Properties of Matter
 - PS1.B: Chemical Reactions
 - PS1.C: Nuclear Processes
- PS2: Motion and Stability: Forces and Interactions
 - PS2.A: Forces and Motion
 - PS2.B: Types of Interactions
 - PS2.C: Stability and Instability in Physical Systems
- PS3: Energy
 - 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
 - PS4.A: Wave Properties
 - PS4.B: Electromagnetic Radiation
 - PS4.C: Information Technologies and Instrumentation

Disciplinary Core Ideas in Life Science

- LS1: From Molecules to Organisms: Structures and Processes
 - LS1.A: Structure and Function
 - LS1.B: Growth and Development of Organisms
 - LS1.C: Organization for Matter and Energy Flow in Organisms
 - LS1.D: Information Processing
- LS2: Ecosystems: Interactions, Energy, and Dynamics
 - LS2.A: Interdependent Relationships in Ecosystems
 - LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
 - LS2.C: Ecosystem Dynamics, Functioning, and Resilience
 - LS2.D: Social Interactions and Group Behavior
- LS3: Heredity: Inheritance and Variation of Traits
 - LS3.A: Inheritance of Traits
 - LS3.B: Variation of Traits
- LS4: Biological Evolution: Unity and Diversity
 - LS4.A: Evidence of Common Ancestry
 - LS4.B: Natural Selection
 - LS4.C: Adaptation
 - LS4.D: Biodiversity and Human Evolution

Disciplinary Core Ideas in Earth and Space Science

- ESS1: Earth's Place in the Universe
 - ESS1.A: The Universe and Its Stars
 - ESS1.B: Earth and the Solar System
 - ESS1.C: The History of Planet Earth
- ESS2: Earth's Systems
 - ESS2.A: Earth Materials and Systems
 - ESS2.B: Plate Tectonics and Earth's History
 - ESS2.C: The Roles of Water in Earth's Systems
 - ESS2.D: Weather and Climate
 - ESS2.E: Biogeology
- ESS3: Earth and Human Activity
 - ESS3.A: Natural Resources
 - ESS3.B: Natural Hazards
 - ESS3.C: Human Impacts on Earth Systems
 - ESS3.D: Global Climate Change

The NSTA Quick-Reference Guide to the Three Dimensions

Disciplinary Core Ideas in Engineering, Technology, and Applications of Science

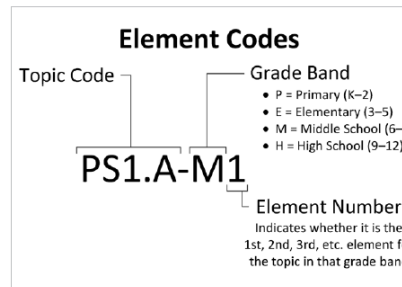
- ETS1: Engineering Design
 - ETS1.A: Defining and Delimiting an Engineering Problem
 - ETS1.B: Developing Possible Solutions
 - ETS1.C: Optimizing the Design Solution

Connections to Engineering, Technology, and Applications of Science

- INFLU: Influence of Science, Engineering, and Technology on Society and the Natural World
- INTER: Interdependence of Science, Engineering, and Technology

Connections to the Nature of Science

- VOM: Scientific Investigations Use a Variety of Methods
- BEE: Science Knowledge Is Based on Empirical Evidence
- OTR: Scientific Knowledge Is Open to Revision in Light of New Evidence
- ENP: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- WOK: Science Is a Way of Knowing
- AOC: Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- HE: Science Is a Human Endeavor
- AQAW: Science Addresses Questions About the Natural and Material World



Topic Codes



Science and Engineering Practices

- AQDP:** Asking Questions and Defining Problems
MOD: Developing and Using Models
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INTER: Interdependence of Science, Engineering, and Technology



Element Codes

Topic Code

Grade Band

- P = Primary (K–2)
- E = Elementary (3–5)
- M = Middle School (6–8)
- H = High School (9–12)

PS1.A-M1

Element Number

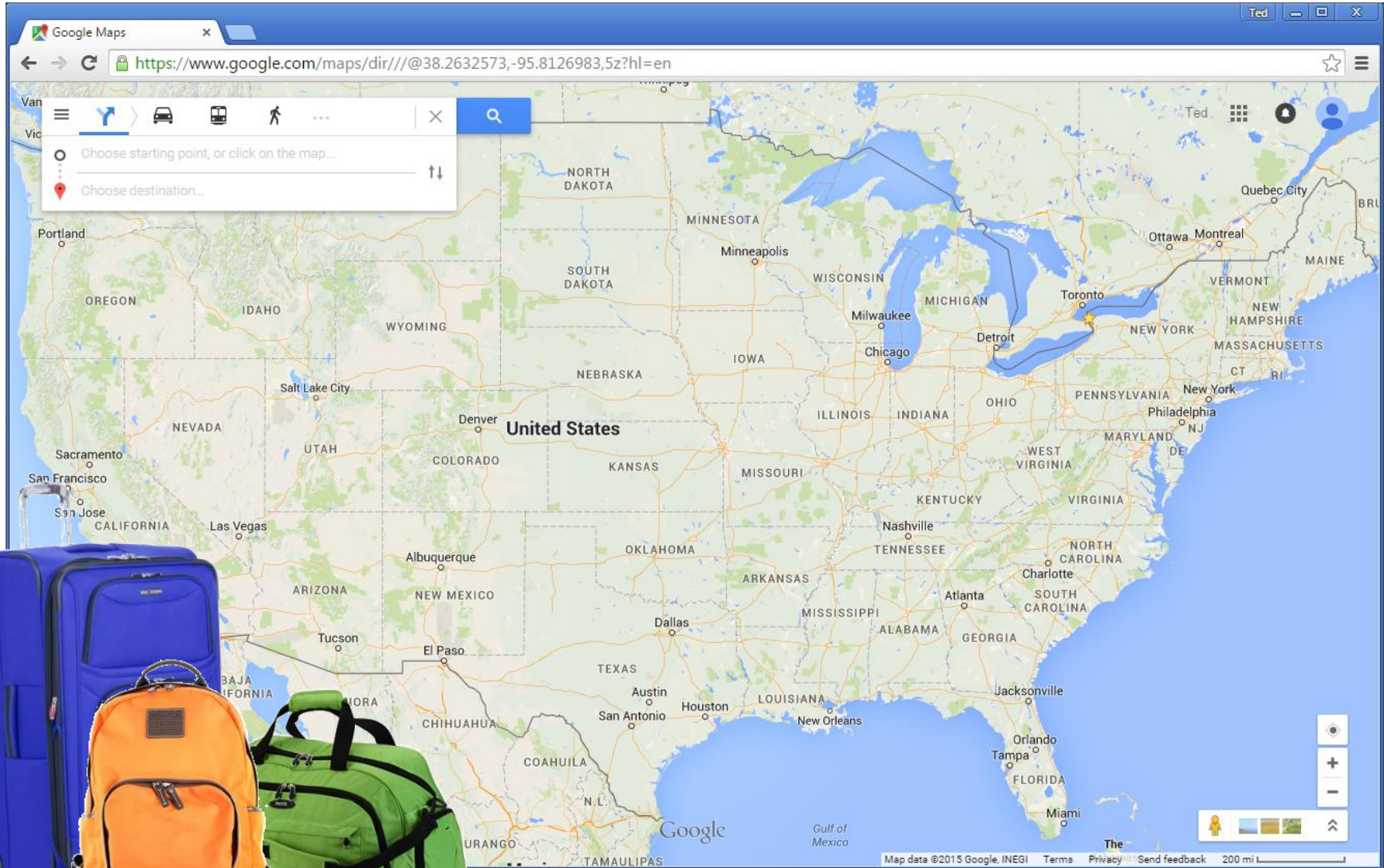
Indicates whether it is the 1st, 2nd, 3rd, etc. element for the topic in that grade band

Questions?



Unpacking The Practices

The Trip Analogy

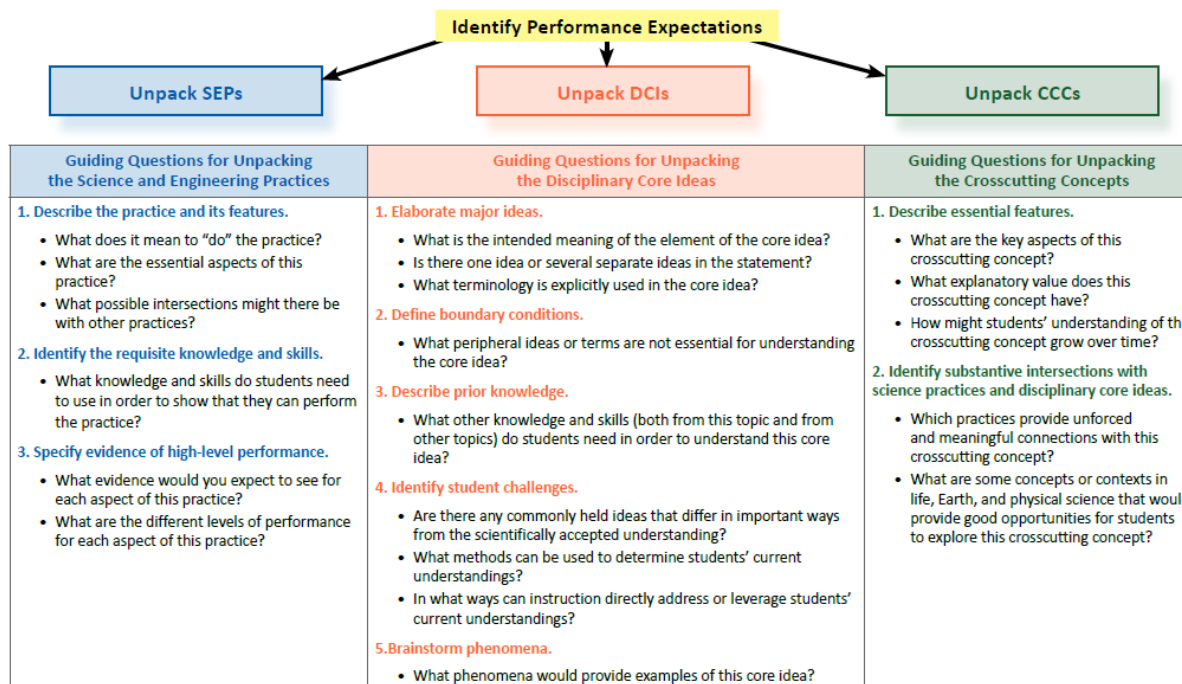


Guiding Questions for Unpacking the Standards



The NSTA Quick-Reference Guide to the Three Dimensions

Guiding Questions for Unpacking the Standards



From: The NSTA Atlas of the Three Dimensions (Willard, 2020) based on procedures described in Creating and Using Instructionally Supportive Assessments in NGSS Classrooms (Harris, Krajcik, and Pellegrino, forthcoming).

Guiding Questions for Unpacking the Science and Engineering Practices



1. Describe the practice and its features.

- What does it mean to “do” the practice?
- What are the essential aspects of this practice?
- What possible intersections might there be with other practices?

2. Identify the requisite knowledge and skills.

- What knowledge and skills do students need to use in order to show that they can perform the practice?

3. Specify evidence of high-level performance.

- What evidence would you expect to see for each aspect of this practice?
- What are the different levels of performance for each aspect of this practice?

Description from the Framework



CHAPTER 1

Science and Engineering Practice 1: Asking Questions and Defining Problems

Questions are the engine that drive science and engineering.

Science asks

- What exists and what happens?
- Why does it happen?
- How does one know?

Engineering asks

- What can be done to address a particular human need or want?
- How can the need be better specified?
- What tools and technologies are available, or could be developed, for addressing this need?

Both science and engineering ask

- How does one communicate about phenomena, evidence, explanations, and design solutions?

Asking questions is essential to developing scientific habits of mind. Even for individuals who do not become scientists or engineers, the ability to ask well-defined questions is an important component of science literacy, helping to make them critical consumers of scientific knowledge.

Scientific questions arise in a variety of ways. They can be driven by curiosity about the world (e.g., Why is the sky blue?). They can be inspired by a model's or theory's predictions or by attempts to extend or refine a model or theory (e.g., How does the particle model of matter explain the incompressibility of liquids?). Or they can result from the need to provide better solutions to a problem. For example, the question of why it is impossible to siphon water above a height of 32 feet led Evangelista Torricelli (17th-century inventor of the barometer) to his discoveries about the atmosphere and the identification of a vacuum.

Questions are also important in engineering. Engineers must be able to ask probing questions in order to define an engineering problem. For example, they may ask: What is the need or desire that underlies the problem? What are the criteria (specifications) for a successful solution? What are the constraints? Other questions arise when generating possible solutions: Will this solution meet the design criteria? Can two or more ideas be combined to produce a better solution? What are the possible trade-offs? And more questions arise when testing solutions: Which ideas should be tested? What evidence is needed to show which idea is optimal under the given constraints?

The experience of learning science and engineering should therefore develop students' ability to ask—and indeed, encourage them to ask—well-formulated questions that can be investigated empirically. Students also need to recognize the distinction between questions

Descriptions of the Science and Engineering Practices From the Framework

that can be answered empirically and those that are answerable only in other domains of knowledge or human experience.

GOALS

By grade 12, students should be able to

- Ask questions about the natural and human-built worlds—for example: Why are there seasons? What do bees do? Why did that structure collapse? How is electric power generated?
- Distinguish a scientific question (e.g., Why do helium balloons rise?) from a nonscientific question (Which of these colored balloons is the prettiest?).
- Formulate and refine questions that can be answered empirically in a science classroom and use them to design an inquiry or construct a pragmatic solution.
- Ask probing questions that seek to identify the premises of an argument, request further elaboration, refine a research question or engineering problem, or challenge the interpretation of a data set—for example: How do you know? What evidence supports that argument?
- Note features, patterns, or contradictions in observations and ask questions about them.
- For engineering, ask questions about the need or desire to be met in order to define constraints and specifications for a solution.

PROGRESSION

Students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. For engineering, they should ask questions to define the problem to be solved and to elicit ideas that lead to the constraints and specifications for its solution. As they progress across the grades, their questions should become more relevant, focused, and sophisticated. Facilitating such evolution will require a classroom culture that respects and values good questions, that offers students opportunities to refine their questions and questioning strategies, and that incorporates the teaching of effective questioning strategies across all grade levels. As a result, students will become increasingly proficient at posing questions that request relevant empirical evidence; that seek to refine a model, an explanation, or an engineering problem; or that challenge the premise of an argument or the suitability of a design.

K–12 Progression



AQDP: Ask Questions and Define Problems			Science and Engineering Practices
<i>Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.</i>	<i>Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships.</i>	<i>Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, clarify arguments and models.</i>	<i>Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.</i>
AQDP-P1: Ask questions based on observations to find more information about the natural and/or designed world(s).	AQDP-E1: Ask questions about what would happen if a variable is changed.	AQDP-M1: Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. AQDP-M2: Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument. AQDP-M3: Ask questions to determine relationships between independent and dependent variables and relationships in models. AQDP-M4: Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.	AQDP-H1: Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. AQDP-H2: Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. AQDP-H3: Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. AQDP-H4: Ask questions to clarify and refine a model, an explanation, or an engineering problem.
AQDP-P2: Ask and/or identify questions that can be answered by an investigation.	AQDP-E2: Identify scientific (testable) and non-scientific (non-testable) questions. AQDP-E3: Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.	AQDP-M5: Ask questions that require sufficient and appropriate empirical evidence to answer. AQDP-M6: Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	AQDP-H5: Evaluate a question to determine if it is testable and relevant. AQDP-H6: Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
<i>No elements in his grade band</i>	<i>No elements in this grade band</i>	AQDP-M7: Ask questions that challenge the premise(s) of an argument or the interpretation of a data set.	AQDP-H7: Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of the design.
AQDP-P3: Define a simple problem that can be solved through the development of a new or improved object or tool.	AQDP-E4: Use prior knowledge to describe problems that can be solved. AQDP-E5: Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.	AQDP-M8: Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	AQDP-H8: Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations. AQDP-H9: Analyze complex real-world problems by specifying criteria and constraints for successful solutions.

Your Task



1. Read the description of the practice Ask Questions and Define Problems from the *Framework* that appears on pages 2-3 of the *Quick Reference Guide*
2. Study the K–12 progression of the elements of the practice Ask Questions and Define Problems that appears on page 65 of the *Quick Reference Guide*
3. Based on the Framework description and K–12 progression, answer the questions on page 47 of the *Quick Reference Guide*

Guiding Questions for Unpacking the Science and Engineering Practices



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Questions?



Contact Information



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Thank Today's Presenter



Ted Willard

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Collection of Resources



This collection includes the slides (as PDF), handouts and other resources.



Link to the collection:

https://my.nsta.org/collection/X_smsir3xHcA_E

NSTA Web Seminars



Science Update: Exploring Seamounts of the Atlantic and Pacific
June 23, 7:00 PM ET

NIH Genome: Unlocking Life's Code, Session 1: Food Allergy Storyline
Unit Part 1
July 12, 7:00 PM ET

NIH Genome: Unlocking Life's Code, Session 2: Food Allergy Storyline
Unit Part 2
July 13, 7:00 PM ET

Picture-Perfect STEM Train-the-Trainer
July 13, 11:00 AM to 1:00 PM ET

Science Update: Is Cancer Inevitable?
July 14, 7:00 PM ET

NIH Genome: Unlocking Life's Code: Playlist
July 27, 7:00 PM ET



<https://my.nsta.org/webseminars>

Thanks to the NSTA Virtual Learning Team



National Science Teaching Association

Tricia Shelton, Chief Learning Officer

Flavio Mendez, Assistant Executive Director

Kate Soriano, Standards Implementation Specialist

Wendy Binder, Program Director

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Patrice Scinta, Curriculum Writer

Holly Hereau, Instructional Materials and Professional
Learning Specialist

Emilee Clemens, Project Specialist

Eddie Hausknecht, Sr. Mgr. Web Development

Don Boonstra, Technical Coordinator

This concludes today's program.