

## APPENDIX A – Conceptual Shifts in the Next Generation Science Standards

The Next Generation Science Standards (NGSS) provide an important opportunity to improve not only science education but also student achievement. Based on the *Framework for K–12 Science Education*, the NGSS are intended to reflect a new vision for American science education. The following conceptual shifts in the NGSS demonstrate what is new and different about the NGSS:

### 1. K-12 Science Education Should Reflect the Interconnected Nature of Science as it is Practiced and Experienced in the Real World.

*“The framework is designed to help realize a vision for education in the sciences and engineering in which students, over multiple years of school, actively engage in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields.”<sup>1</sup>*

The vision represented in the *Framework* is new in that students must be engaged at the nexus of the three dimensions:

1. Science and Engineering Practices,
2. Crosscutting Concepts, and
3. Disciplinary Core Ideas.

Currently, most state and district standards express these dimensions as separate entities, leading to their separation in both instruction and assessment. Given the importance of science and engineering in the 21<sup>st</sup> century, students require a sense of contextual understanding with regard to scientific knowledge, how it is acquired and applied, and how science is connected through a series of concepts that help further our understanding of the world around us. Student performance expectations have to include a student’s ability to apply a practice to content knowledge. Performance expectations thereby focus on understanding and application as opposed to memorization of facts devoid of context. The *Framework* goes on to emphasize that:

*“...learning about science and engineering involves integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering design. Thus the framework seeks to illustrate how knowledge and practice must be intertwined in designing learning experiences in K–12 science education.”<sup>2</sup>*

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<sup>1</sup> (2011). *A Framework for K-12 Science Education: Practices, crosscutting concepts, and core ideas*. (p. 10). Washington, DC: The National Academies Press. Retrieved from [http://www.nap.edu/catalog.php?record\\_id=13165](http://www.nap.edu/catalog.php?record_id=13165)

<sup>2</sup> (2011). *A Framework for K-12 Science Education: Practices, crosscutting concepts, and core ideas*. (p. 11). Washington, DC: The National Academies Press. Retrieved from [http://www.nap.edu/catalog.php?record\\_id=13165](http://www.nap.edu/catalog.php?record_id=13165)

**2. The Next Generation Science Standards are student performance expectations – NOT curriculum.** Even though within each performance expectation Science and Engineering Practices (SEP) are partnered with a particular Disciplinary Core Idea (DCI) and Crosscutting Concept (CC) in the NGSS, these intersections do not predetermine how the three are linked in curriculum, units, or lessons. Performance expectations simply clarify the expectations of what students will know and be able to do by the end of the grade or grade band. Additional work will be needed to create coherent instructional programs that help students achieve these standards.

As stated previously, past science standards at both the state and district levels have treated the three dimensions of science as separate and distinct entities leading to preferential treatment in assessment or instruction. It is essential to understand that the emphasis placed on a particular Science and Engineering Practice or Crosscutting Concept in a performance expectation is not intended to limit instruction, but to make clear the intent of the assessments.

An example of this is illustrated in two performance expectations in high school physical sciences that use the practice of modeling. Models are basically used for three reasons: 1) to represent or describe; 2) to collect data; or 3) to predict. The first use is typical in schools since models and representations are usually synonymous. However, the use of models to collect data or to predict phenomena is new, for example:

*Construct models to explain changes in nuclear energies during the processes of fission, fusion, and radioactive decay and the nuclear interactions that determine nuclear stability.*

and

*Use system models (computer or drawings) to construct molecular-level explanations to predict the behavior of systems where a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.*

In the first performance expectation, models are used with nuclear processes to explain changes. A scientific explanation requires evidence to support the explanation, so students will be called upon to construct a model for the purpose of gathering evidence to explain these changes. Additionally, they will be required to use models to both explain and predict the behavior of systems in equilibrium. Again, the models will have to be used to collect data, but they will be further validated in their ability to predict the state of a system. In both cases, students will need a deep understanding of the content, as well as proficiency in the ability to construct and use models for various applications. The practice of modeling will need to be taught throughout the



year—and indeed throughout the entire K–12 experience—as opposed to during one two-week unit of instruction.

The goal of the NGSS is to be clear about which practice students are responsible for in terms of assessment, but these practices and crosscutting concepts should occur throughout each school year.

### 3. The Science Concepts in the NGSS Build Coherently from K–12.

The focus on a few Disciplinary Core Ideas is a key aspect of a coherent science education. The *Framework* identified a basic set of core ideas that are meant to be understood by the time a student completes high school:

*“To develop a thorough understanding of scientific explanations of the world, students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas’ interconnections over a period of years rather than weeks or months [1]. This sense of development has been conceptualized in the idea of learning progressions [1, 25, 26]. If mastery of a core idea in a science discipline is the ultimate educational destination, then well-designed learning progressions provide a map of the routes that can be taken to reach that destination. Such progressions describe both how students’ understanding of the idea matures over time and the instructional supports and experiences that are needed for them to make progress.”<sup>3</sup>*

There are two key points that are important to understand:

- First, focus and coherence must be a priority. What this means to teachers and curriculum developers is that the same ideas or details are not covered each year. Rather, a progression of knowledge occurs from grade band to grade band that gives students the opportunity to learn more complex material, leading to an overall understanding of science by the end of high school. Historically, science education was taught as a set of disjointed and isolated facts. The *Framework* and the NGSS provide a more coherent progression aimed at overall scientific literacy with instruction focused on a smaller set of ideas and an eye on what the student should have already learned and what they will learn at the next level.
- Second, the progressions in the NGSS automatically assume that previous material has been learned by the student. Choosing to omit content at any grade level or band will impact the success of the student in understanding the core ideas and put additional responsibilities on teachers later in the process.

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<sup>3</sup> (2011). *A Framework for K-12 Science Education: Practices, crosscutting concepts, and core ideas*. (p. 26). Washington, DC: The National Academies Press. Retrieved from [http://www.nap.edu/catalog.php?record\\_id=13165](http://www.nap.edu/catalog.php?record_id=13165)

#### **4. The NGSS Focus on Deeper Understanding of Content as well as Application of Content.**

The *Framework* identified a smaller set of Disciplinary Core Ideas that students should know by the time they graduate from high school, and the NGSS are written to focus on the same. It is important that teachers and curriculum/assessment developers understand that the focus is on the core ideas—not necessarily the facts that are associated with them. The facts and details are important evidence, but not the sole focus of instruction. The Framework states:

*“The core ideas also can provide an organizational structure for the acquisition of new knowledge. Understanding the core ideas and engaging in the scientific and engineering practices helps to prepare students for broader understanding, and deeper levels of scientific and engineering investigation, later on—in high school, college, and beyond. One rationale for organizing content around core ideas comes from studies comparing experts and novices in any field. Experts understand the core principles and theoretical constructs of their field, and they use them to make sense of new information or tackle novel problems. Novices, in contrast, tend to hold disconnected and even contradictory bits of knowledge as isolated facts and struggle to find a way to organize and integrate them [24]. The assumption, then, is that helping students learn the core ideas through engaging in scientific and engineering practices will enable them to become less like novices and more like experts.”<sup>4</sup>*

#### **5. Science and Engineering are Integrated in the NGSS, from K–12.**

The idea of integrating technology and engineering into science standards is not new. Chapters on the nature of technology and the human-built world were included in *Science for All Americans* (AAAS 1989) and *Benchmarks for Science Literacy* (AAAS 1993, 2008). Standards for “Science and Technology” were included for all grade spans in the *National Science Education Standards* (NRC 1996).

Despite these early efforts, however, engineering and technology have not received the same level of attention in science curricula, assessments, or the education of new science teachers as the traditional science disciplines have. A significant difference in the *Next Generation Science Standards* (NGSS) is the integration of engineering and technology into the structure of science education. This integration is achieved by raising engineering design to the same level as scientific inquiry in classroom instruction when teaching science disciplines at all levels and by giving core ideas of engineering and technology the same status as those in other major science disciplines.

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<sup>4</sup> (2011). *A Framework for K-12 Science Education: Practices, crosscutting concepts, and core ideas*. (p. 25). Washington, DC: The National Academies Press. Retrieved from [http://www.nap.edu/catalog.php?record\\_id=13165](http://www.nap.edu/catalog.php?record_id=13165)



The rationale for this increased emphasis on engineering and technology rests on two positions taken in *A Framework for K–12 Science Education* (NRC 2011). One position is aspirational, the other practical.

From an aspirational standpoint, the *Framework* points out that science and engineering are needed to address major world challenges such as generating sufficient clean energy, preventing and treating diseases, maintaining supplies of food and clean water, and solving the problems of global environmental change that confront society today. These important challenges will motivate many students to continue or initiate their study of science and engineering.

From a practical standpoint, the *Framework* notes that engineering and technology provide opportunities for students to deepen their understanding of science by applying their developing scientific knowledge to the solution of practical problems. Both positions converge on the powerful idea that by integrating technology and engineering into the science curriculum, teachers can empower their students to use what they learn in their everyday lives.

#### **6. The NGSS are designed to prepare students for college, career, and citizenship.**

There is no doubt that science and science education are central to the lives of all Americans. Never before has our world been so complex and science knowledge so critical to making sense of it all. When comprehending current events, choosing and using technology, or making informed decisions about one's healthcare, understanding science is key. Science is also at the heart of the United States' ability to continue to innovate, lead, and create the jobs of the future. All students no matter what their future education and career path must have a solid K–12 science education in order to be prepared for college, careers, and citizenship.

#### **7. The NGSS and Common Core State Standards (English Language Arts and Mathematics) are Aligned.**

The timing of the release of NGSS comes as most states are implementing the Common Core State Standards (CCSS) in English Language Arts and Mathematics. This is important to science for a variety of reasons. First, there is an opportunity for science to be part of a child's comprehensive education. The NGSS are aligned with the CCSS to ensure a symbiotic pace of learning in all content areas. The three sets of standards overlap in meaningful and substantive ways and offer an opportunity to give all students equitable access to learning standards.

Some important work is already in progress regarding the implications and advantages to the CCSS and NGSS. Stanford University recently released 13 papers on a variety of issues related to language and literacy in the content areas of the CCSS and NGSS.<sup>5</sup>

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<sup>5</sup> Stanford University. (2012). *Understanding language*. Retrieved from <http://ell.stanford.edu/papers>.



# K. Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

## K. Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

Students who demonstrate understanding can:

- K-LS1-1. Use observations to describe patterns of what plants and animals (including humans) need to survive.** [Clarification Statement: Examples of patterns could include that animals need to take in food but plants do not; the different kinds of food needed by different types of animals; the requirement of plants to have light; and that all living things need water.]
- K-ESS2-2. Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.** [Clarification Statement: Examples of plants and animals changing their environment could include a squirrel digs in the ground to hide its food and tree roots can break concrete.]
- K-ESS3-1. Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live.** [Clarification Statement: Examples of relationships could include that deer eat buds and leaves, therefore, they usually live in forested areas, and grasses need sunlight so they often grow in meadows. Plants, animals, and their surroundings make up a system.]
- K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.\*** [Clarification Statement: Examples of human impact on the land could include cutting trees to produce paper and using resources to produce bottles. Examples of solutions could include reusing paper and recycling cans and bottles.]

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Developing and Using Models</b> Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.</p> <ul style="list-style-type: none"> <li>▪ Use a model to represent relationships in the natural world. (K-ESS3-1)</li> </ul> <p><b>Analyzing and Interpreting Data</b> Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.</p> <ul style="list-style-type: none"> <li>▪ Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. (K-LS1-1)</li> </ul> <p><b>Engaging in Argument from Evidence</b> Engaging in argument from evidence in K–2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s).</p> <ul style="list-style-type: none"> <li>▪ Construct an argument with evidence to support a claim. (K-ESS2-2)</li> </ul> <p><b>Obtaining, Evaluating, and Communicating Information</b> Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.</p> <ul style="list-style-type: none"> <li>▪ Communicate solutions with others in oral and/or written forms using models and/or drawings that provide detail about scientific ideas. (K-ESS3-3)</li> </ul> <p style="text-align: center;">----- <i>Connections to Nature of Science</i> -----</p> <p><b>Scientific Knowledge is Based on Empirical Evidence</b></p> <ul style="list-style-type: none"> <li>▪ Scientists look for patterns and order when making observations about the world. (K-LS1-1)</li> </ul>	<p><b>LS1.C: Organization for Matter and Energy Flow in Organisms</b></p> <ul style="list-style-type: none"> <li>▪ All animals need food in order to live and grow. They obtain their food from plants or from other animals. Plants need water and light to live and grow. (K-LS1-1)</li> </ul> <p><b>ESS2.E: Biogeology</b></p> <ul style="list-style-type: none"> <li>▪ Plants and animals can change their environment. (K-ESS2-2)</li> </ul> <p><b>ESS3.A: Natural Resources</b></p> <ul style="list-style-type: none"> <li>▪ Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do. (K-ESS3-1)</li> </ul> <p><b>ESS3.C: Human Impacts on Earth Systems</b></p> <ul style="list-style-type: none"> <li>▪ Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things. (secondary to K-ESS2-2),(K-ESS3-3)</li> </ul> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>▪ 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. (secondary to K-ESS3-3)</li> </ul>	<p><b>Patterns</b></p> <ul style="list-style-type: none"> <li>▪ Patterns in the natural and human designed world can be observed and used as evidence. (K-LS1-1)</li> </ul> <p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>▪ Events have causes that generate observable patterns. (K-ESS3-3)</li> </ul> <p><b>Systems and System Models</b></p> <ul style="list-style-type: none"> <li>▪ Systems in the natural and designed world have parts that work together. (K-ESS2-2),(K-ESS3-1)</li> </ul>
<p><i>Connections to other DCIs in kindergarten: K.ETS1.A (K-ESS3-3)</i></p> <p><i>Articulation of DCIs across grade-levels: 1.LS1.A (K-LS1-1),(K-ESS3-1); 2.LS2.A (K-LS1-1); 2.ETS1.B (K-ESS3-3); 3.LS2.C (K-LS1-1); 3.LS4.B (K-LS1-1); 4.ESS2.E (K-ESS2-2); 4.ESS3.A (K-ESS3-3); 5.LS1.C (K-LS1-1); 5.LS2.A (K-LS1-1),(K-ESS3-1); 5.ESS2.A (K-ESS2-2),(K-ESS3-1); 5.ESS3.C (K-ESS3-3)</i></p> <p><i>Common Core State Standards Connections:</i></p> <p><b>ELA/Literacy –</b></p> <p><b>RI.K.1</b> With prompting and support, ask and answer questions about key details in a text. (K-ESS2-2)</p> <p><b>W.K.1</b> Use a combination of drawing, dictating, and writing to compose opinion pieces in which they tell a reader the topic or the name of the book they are writing about and state an opinion or preference about the topic or book. (K-ESS2-2)</p> <p><b>W.K.2</b> Use a combination of drawing, dictating, and writing to compose informative/explanatory texts in which they name what they are writing about and supply some information about the topic. (K-ESS2-2),(K-ESS3-3)</p> <p><b>W.K.7</b> Participate in shared research and writing projects (e.g., explore a number of books by a favorite author and express opinions about them). (K-LS1-1)</p> <p><b>SL.K.5</b> Add drawings or other visual displays to descriptions as desired to provide additional detail. (K-ESS3-1)</p> <p><b>Mathematics –</b></p> <p><b>MP.2</b> Reason abstractly and quantitatively. (K-ESS3-1)</p> <p><b>MP.4</b> Model with mathematics. (K-ESS3-1)</p> <p><b>K.CC</b> Counting and Cardinality (K-ESS3-1)</p> <p><b>K.MD.A.2</b> Directly compare two objects with a measurable attribute in common, to see which object has “more of”/“less of” the attribute, and describe the difference. (K-LS1-1)</p>		

\*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

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