

A New Vision for Science Education

Implications of the Vision of the Framework for K-12 Science Education and the Next Generation Science Standards

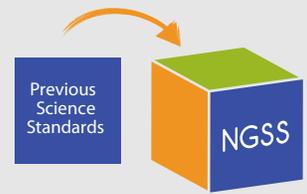
SCIENCE EDUCATION WILL INVOLVE LESS:	SCIENCE EDUCATION WILL INVOLVE MORE:
Rote memorization of facts and terminology	Facts and terminology learned as needed while developing explanations and designing solutions supported by evidence-based arguments and reasoning.
Learning of ideas disconnected from questions 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

Next Generation Science Standards (NGSS)



WHAT ARE THE NEW SCIENCE STANDARDS?

The Next Generation Science Standards (NGSS) are a new set of K–12 science standards that were developed by states, for states. The NGSS identify scientific and engineering practices, crosscutting concepts, and core ideas in science that all K–12 students should master in order to prepare for success in college and 21st-century careers.



WHY ARE THEY IMPORTANT?

It has been more than 17 years since the National Research Council and the American Association for the Advancement of Science produced their reports from which most state science standards are based. Since then, there have been major advances in science and our understanding of how students learn science. Students need the kind of preparation that gives them the tools and skills necessary to succeed in a rapidly and continuously changing world.

When current students graduate from high school, more jobs will require skills in science, technology, engineering, and mathematics (STEM) than in the past. The NGSS provide a strong science education that equips students with the ability to think critically, analyze information, and solve complex problems — the skills needed to pursue opportunities within and beyond STEM fields.

HOW WERE THEY DEVELOPED?

The NGSS were developed through a collaborative state-led process. Science supervisors from 26 states worked with a 40-member writing team—which included teachers, working scientists, and education researchers—to develop the draft standards, based on the National Research Council’s document *A Framework for K–12 Science Education*. Each of the 26 states established a broad-based committee to review draft standards and provide feedback. In addition to those reviews, a larger stakeholder team composed of hundreds of members representing K–12 educators, administrators, higher-education faculty, scientists, engineers, business leaders, policymakers, and key organizations provided feedback during five review periods. The draft standards went through two public review periods and received comments from more than 10,000 individuals.



HOW WILL THE NGSS SUPPORT COLLEGE AND CAREER READINESS FOR ALL STUDENTS AND PREPARE THEM TO SUCCEED IN THE GLOBAL ECONOMY?



A high-quality, robust science education means students will develop an in-depth understanding of content and will gain knowledge and develop skills—communication, collaboration, inquiry, problem solving, and flexibility—that will serve them throughout their educational and professional lives.

The NGSS were benchmarked against countries whose students perform well in science and engineering fields, including Finland, South Korea, China, Canada, England, Hungary, Ireland, Japan, and Singapore.

WHAT WILL THE NGSS LOOK LIKE IN THE CLASSROOM?

High-quality education standards allow educators to teach effectively, moving their practice toward how students learn best—in a hands-on, collaborative, and integrated environment rooted in inquiry and discovery. Teaching based on the NGSS calls for more student-centered learning that enables students to think on their own, problem solve, communicate, and collaborate—in addition to learning important scientific concepts.

THE NGSS OFFER FIVE INNOVATIONS FOR TEACHING

1

Three Dimensional Learning: There are three equally important, distinct dimensions to learning science included in the NGSS: Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. The NGSS connect all three dimensions. To prepare students for success in college and 21st century careers, the NGSS also connect scientific principles to real-world situations, allowing for more engaging and relevant instruction to explore complicated topics.

2

All three dimensions build coherent learning progressions: The NGSS provide students with continued opportunities to engage in and develop a deeper understanding of each of the three dimensions of science. Building on the knowledge and skills gained from each grade—from elementary through high school—students have multiple opportunities to revisit and expand their understanding of all three dimensions by the end of high school.

3

Students engage with phenomena and design solutions: In instructional systems aligned to the NGSS, the goal of instruction is for students to be able to explain real-world phenomena and to design solutions using their understanding of the Disciplinary Core Ideas. Students can achieve this goal by engaging in the Science and Engineering Practices and applying the Crosscutting Concepts.

4

Engineering and the Nature of Science is integrated into science: Some unique aspects of engineering (e.g., identifying problems) are incorporated throughout the NGSS. In addition, unique aspects of the nature of science (e.g., how theories are developed) are also included throughout the NGSS as practices and crosscutting concepts.

5

Science is connected to math and literacy: The NGSS not only provide for coherence in science instruction and learning but the standards also connect science with mathematics and English Language Arts. This meaningful and substantive overlapping of skills and knowledge affords all students equitable access to the learning standards.

COMMON MISCONCEPTIONS ABOUT THE NGSS

Myth: The NGSS were developed by the United States Department of Education.

FACT: The Next Generation Science Standards (NGSS) were developed through a collaborative state-led process. Twenty-six states volunteered to work with the 40 members of the writing team to lead the development of the standards, and each state formed broad-based committees to work on the standards.

Myth: The NGSS were developed without public input.

FACT: The draft standards received comments from more than 10,000 individuals during each of two public review periods. These comments came from teachers, school and school district discussion groups, scientific societies, parents, and students. In addition, an expert team composed of hundreds of members representing K–12 educators, administrators, higher education faculty, scientists, engineers, business leaders, policymakers, and key organizations provided confidential feedback during critical points of the development process.

Myth: The NGSS were developed without teacher input.

FACT: To develop the standards, the science supervisors in the 26 lead states worked with a 40-member writer team, all of whom were education experts and more than half of whom were practicing K–12 teachers. Thousands of teachers also provided comments to the draft standards during the two public review periods and as part of expert review panels.

Myth: The NGSS will force states and districts to adopt a uniform curriculum.

FACT: The NGSS are standards, not curricula. Local districts, schools, and classroom teachers will continue to determine their own curriculum, including what is taught throughout the year and how it is taught.

Myth: The NGSS are part of the Common Core.

FACT: The NGSS are not part of the Common Core State Standards (CCSS). The CCSS only cover mathematics and English Language Arts (ELA)/literacy whereas the NGSS are a separate set of K–12 science standards that were drafted through a distinctly different process.

Myth: The NGSS are funded with federal dollars.

FACT: No federal funding, grants, or formula funding is tied to the adoption of the NGSS nor was used to develop them. The Carnegie Corporation of New York, a foundation dedicated to improving science education in the U.S., provided funding support for the development of the NGSS.

Myth: The NGSS are too rigorous for students who have no intention of pursuing science after high school.

FACT: Science is a key factor in students' ability to think critically and innovate. All students need strong foundational knowledge in science to tackle long-term and difficult issues that face our generation and future generations. A strong science education equips students with skills that are necessary for lasting success in their postsecondary lives and careers.

Myth: The NGSS are not rigorous enough for students interested in advanced classes in high school and beyond.

FACT: The NGSS does not set a ceiling for student achievement. Students who wish to take advanced coursework will still have the opportunity to do so, and the NGSS will provide them with a solid academic foundation for college-level science courses.

Conceptual Shifts

The Next Generation Science Standards (NGSS) provide an opportunity to improve K-12 science education to better prepare all students to be science literate. The NGSS are based on the Framework for K–12 Science Education, a report from the National Research Council, which describes a new vision for teaching and learning science. The conceptual shifts listed below highlight what is new and different about the NGSS. A more thorough description of each shift can be found at the following link:

<http://www.nextgenscience.org/sites/ngss/files/Appendix%20A%20-%204.11.13%20Conceptual%20Shifts%20in%20the%20Next%20Generation%20Science%20Standards.pdf>

1. K-12 Science Education Should Reflect the Interconnected Nature of Science as it is Practiced and Experienced in the Real World.
2. The Next Generation Science Standards are student performance expectations – NOT curriculum.
3. The Science Concepts in the NGSS Build Coherently from K–12.
4. The NGSS Focus on Deeper Understanding of Content as well as Application of Content.
5. Science and Engineering are integrated in the NGSS, from K–12.
6. The NGSS are designed to prepare students for college, career, and citizenship.
7. The NGSS and Common Core State Standards (English Language Arts and Mathematics) are aligned.

The shifts can be summarized as “Science needs to change from students learning about science to students figuring out an explanation or solving a problem” (Reiser, B, online post).

Three Dimensional Learning

Three-Dimensional Learning shifts the focus of the science classroom to environments where students use disciplinary core ideas, crosscutting concepts with scientific practices to explore, examine, and explain how and why phenomena occur and to design solutions to problems, (Krajcik, J, <http://www.activatelearning.com/3-dimensional-learning/>)

Anchoring Phenomena

Constructing an explanation is the basis of student performance in this pedagogical approach. Students generate questions and use these questions to explore the world around them to better understand how things work. The students learn to work like scientists by employing a “claims, evidence, reasoning” approach to understanding and explaining phenomena.

Scientific and Engineering Practices

<http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf>

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

Developing a Scientific Model (brief description of practice)

- The model is a simplified representation that allows us to think about how a system or phenomenon works
- Central features or components of the model are made explicit and visible (including those that are not visible with eyes only)
- Appropriate labels are included to clarify the model's components
- The components of the model are connected by relationships
- The model allows to say something (explain) about what is happening

Crosscutting Concepts

<http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf>

1. Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. 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.
3. 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.
4. 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.
5. 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.
6. Structure and function. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
7. 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

<http://www.nextgenscience.org/sites/ngss/files/Appendix%20E%20-%20Progressions%20within%20NGSS%20-%20052213.pdf>

1. Earth / Space Science
2. Life Science
3. Physical Science
4. Engineering

Here is an example of a core idea in physical science

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)

Three Dimensions of the *Framework for K-12 Science Education* being used to Develop the *Next Generation Science Standards (NGSS)*

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.

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.

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.

Constructing Explanations and Designing Solutions

The products of science are explanations and the products of engineering are solutions.

The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories.

The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

Engaging in Argument from Evidence

Argumentation is the process by which explanations and solutions are reached.

In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits.

Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to identify strengths and weaknesses of claims.

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 correlational relationships.

Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to acquire information that is used to evaluate the merit and validity of claims, methods, and designs.

Disciplinary Core Ideas in Physical Science	Disciplinary Core Ideas in Life Science	Disciplinary Core Ideas in Earth and Space Science	Disciplinary Core Ideas in Engineering, Technology, and the Application of Science
<p>PS1: Matter and Its Interactions PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions PS1.C: Nuclear Processes</p> <p>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</p> <p>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</p> <p>PS4: Waves and Their Applications in Technologies for Information Transfer PS4.A: Wave Properties PS4.B: Electromagnetic Radiation PS4.C: Information Technologies and Instrumentation</p>	<p>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</p> <p>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</p> <p>LS3: Heredity: Inheritance and Variation of Traits LS3.A: Inheritance of Traits LS3.B: Variation of Traits</p> <p>LS4: Biological Evolution: Unity and Diversity LS4.A: Evidence of Common Ancestry and Diversity LS4.B: Natural Selection LS4.C: Adaptation LS4.D: Biodiversity and Humans</p>	<p>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</p> <p>ESS2: Earth’s Systems ESS2.A: Earth Materials and Systems ESS2.B: Plate Tectonics and Large-Scale System Interactions ESS2.C: The Roles of Water in Earth’s Surface Processes ESS2.D: Weather and Climate ESS2.E: Biogeology</p> <p>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</p>	<p>ETS1: Engineering Design ETS1.A: Defining and Delimiting an Engineering Problem ETS1.B: Developing Possible Solutions ETS1.C: Optimizing the Design Solution</p> <p>ETS2: Links Among Engineering, Technology, Science, and Society ETS2.A: Interdependence of Science, Engineering, and Technology ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World</p>

Crosscutting Concepts		
<p>Patterns Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.</p> <p>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.</p>	<p>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.</p> <p>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.</p>	<p>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.</p> <p>Structure and Function The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.</p> <p>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.</p>