

Overview

There are 8 science and engineering practices described in A Science Framework for K-12 Science Education. They are:

- 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](#)

Science and Engineering Practices in the NGSS (my notes)

- [Summary](#)

Practice 1 Asking Questions and Defining Problems ([^](#))

- *Scientific questions are distinguished from other types of questions in that the answers lie in explanations supported by empirical evidence, including evidence gathered by others or through investigation."*
- *engineering begins with defining a problem to solve*
- *Asking questions and defining problems also involves asking questions about data, claims that are made, and proposed designs. It is important to realize that asking a question also leads to involvement in another practice.*

Grades K - 12

- 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.

Grades K-2

- Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.
 - Ask questions based on observations to find more information about the natural and/or designed world(s).
 - Ask and/or identify questions that can be answered by an investigation.
 - Define a simple problem that can be solved through the development of a new or improved object or tool.

Grades 3-5

- Asking questions and defining problems in 3–5 builds on K–2 experiences and progresses to specifying qualitative relationships.
 - Ask questions about what would happen if a variable is changed.
 - Identify scientific (testable) and non-scientific (non- testable) questions.
 - Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
 - Use prior knowledge to describe problems that can be solved.
 - 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.

Practice 2 Developing and Using Models ([^](#))

- *Models include diagrams, physical replicas, mathematical representations, analogies, and computer simulations.*
- *In science, models are used to represent a system (or parts of a system) under study, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and to communicate ideas to others.*
- *models are based upon evidence.*

Grades K - 12

- 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.

Grades K-2

- 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.
- Distinguish between a model and the actual object, process, and/or events the model represents.
- Compare models to identify common features and differences.
- Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).
- Develop a simple model based on evidence to represent a proposed object or tool.

Grades 3-5

- Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.
- Identify limitations of models.
- Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.
- Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.
- Develop and/or use models to describe and/or predict phenomena.
- Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.
- Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system

Practice 3 Planning and Carrying Out Investigations ([^](#))

- *Scientific investigations may be undertaken to describe a phenomenon, or to test a theory or model for how the world works.*
- *The purpose of engineering investigations might be to find out how to fix or improve the functioning of a technological system or to compare different solutions to see which best solves a problem.*
- *Whether students are doing science or engineering, it is always important for them to state the goal of an investigation, predict outcomes, and plan a course of action that will provide the best*

evidence to support their conclusions.

- *Students should design investigations that generate data to provide evidence to support claims they make about phenomena.*
 - *Data aren't evidence until used in the process of supporting a claim.*
 - *Students should use reasoning and scientific ideas, principles, and theories to show why data can be considered evidence.*

Grades K - 12

- Construct drawings or diagrams as representations of events or systems—for example, draw a picture of an insect with labeled features, represent what happens to the water in a puddle as it is warmed by the sun, or represent a simple physical model of a real-world object and use it as the basis of an explanation or to make predictions about how the system will behave in specified circumstances.
- Represent and explain phenomena with multiple types of models—for example, represent molecules with 3-D models or with bond diagrams—and move flexibly between model types when different ones are most useful for different purposes.
- Discuss the limitations and precision of a model as the representation of a system, process, or design and suggest ways in which the model might be improved to better fit available evidence or better reflect a design's specifications. Refine a model in light of empirical evidence or criticism to improve its quality and explanatory power.
- Use (provided) computer simulations or simulations developed with simple simulation tools as a tool for understanding and investigating aspects of a system, particularly those not readily visible to the naked eye.
- Make and use a model to test a design, or aspects of a design, and to compare the effectiveness of different design solutions.

Grades K-2

- Investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
- With guidance, plan and conduct an investigation in collaboration with peers (for K).
- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.
- Evaluate different ways of observing and/or measuring a phenomenon to determine which way can answer a question.
- Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.
- Make observations (firsthand or from media) and/or measurements of a proposed object or tool or solution to determine if it solves a problem or meets a goal.
- Make predictions based on prior experiences.

Grades 3-5

- investigations to answer questions or test solutions to problems in 3–5 builds on K– 2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
 - Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
 - Evaluate appropriate methods and/or tools for collecting data.
 - Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
 - Make predictions about what would happen if a variable changes.
 - Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.
-

Practice 4 Analyzing and Interpreting Data ([^](#))

- *Once collected, data must be presented in a form that can reveal any patterns and relationships and that allows results to be communicated to others.*
- *Engineers often analyze a design by creating a model or prototype and collecting extensive data on how it performs, including under extreme conditions.*
- *Whether analyzing data for the purpose of science or engineering, it is important students present data as evidence to support their conclusions.*

Grades K - 12

- Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis (that is, a possible explanation that predicts a particular and stable outcome) based on a model or theory.
- Decide what data are to be gathered, what tools are needed to do the gathering, and how measurements will be recorded.

- Decide how much data are needed to produce reliable measurements and consider any limitations on the precision of the data.
- Plan experimental or field-research procedures, identifying relevant independent and dependent variables and, when appropriate, the need for controls.
- Consider possible confounding variables or effects and ensure that the investigation's design has controlled for them.

Grades K-2

- Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.
- Record information (observations, thoughts, and ideas).
- Use and share pictures, drawings, and/or writings of observations.
- 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.
- Compare predictions (based on prior experiences) to what occurred (observable events).
- Analyze data from tests of an object or tool to determine if it works as intended.

Grades 3-5

- Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.
- When possible and feasible, digital tools should be used.
- Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.
- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
- Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
- Analyze data to refine a problem statement or the design of a proposed object, tool, or process.
- Use data to evaluate and refine design solutions.

Practice 5 Using Mathematics and Computational Thinking ([^](#))

- *Mathematics often brings these two fields together by enabling engineers to apply the mathematical form of scientific theories and by enabling scientists to use powerful information technologies designed by engineers.*
- *Students are expected to use mathematics to represent physical variables and their relationships, and to make quantitative predictions.*
- *Computers and digital tools can enhance the power of mathematics by automating calculations, approximating solutions to problems that cannot be calculated precisely, and analyzing large*

data sets available to identify meaningful patterns.

- *Students are expected to use laboratory tools connected to computers for observing, measuring, recording, and processing data.*

Grades K - 12

- Analyze data systematically, either to look for salient patterns or to test whether data are consistent with an initial hypothesis.
- Recognize when data are in conflict with expectations and consider what revisions in the initial model are needed.
- Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and information and computer technology to collate, summarize, and display data and to explore relationships between variables, especially those representing input and output.
- Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques.
- Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.
- Collect data from physical models and analyze the performance of a design under a range of conditions.

Grades K-2

- Mathematical and computational thinking in K–2 builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world(s).
- Decide when to use qualitative vs. quantitative data.
- Use counting and numbers to identify and describe patterns in the natural and designed world(s).
- Describe, measure, and/or compare quantitative attributes of different objects and display the data using simple graphs.
- Use quantitative data to compare two alternative solutions to a problem.

Grades 3-5

- Mathematical and computational thinking in 3–5 builds on K–2 experiences and progresses to extending quantitative measurements to a variety of physical properties and using computation and mathematics to analyze data and compare alternative design solutions.
- Decide if qualitative or quantitative data are best to determine whether a proposed object or tool meets criteria for success.
- Organize simple data sets to reveal patterns that suggest relationships.
- Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.
- Create and/or use graphs and/or charts generated from simple algorithms to compare alternative solutions to an engineering problem.

Practice 6 Constructing Explanations and Designing Solutions (△)

- *The goal of science is to construct explanations for the causes of phenomena.*
- *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.*
 - *An explanation includes a claim that relates how a variable or variables relate to another variable or a set of variables.*
 - *A claim is often made in response to a question and in the process of answering the question, scientists often design investigations to generate data.*
- *The goal of engineering is to solve problems.*
 - *In engineering, the goal is a design rather than an explanation.*

Grades K - 12

- Recognize dimensional quantities and use appropriate units in scientific applications of mathematical formulas and graphs.
- Express relationships and quantities in appropriate mathematical or algorithmic forms for scientific modeling and investigations.
- Recognize that computer simulations are built on mathematical models that incorporate underlying assumptions about the phenomena or systems being studied.
- Use simple test cases of mathematical expressions, computer programs, or simulations—that is, compare their outcomes with what is known about the real world—to see if they “make sense.”
- Use grade-level-appropriate understanding of mathematics and statistics in analyzing data.

Grades K-2

- Explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.
- Make observations (first hand or from media) to construct an evidence-based account for natural phenomena.
- Use tools and/or materials to design and/or build a device that solves a specific problem or a solution to a specific problem.
- Generate and/or compare multiple solutions to a problem.

Grades 3 - 5

- Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe

and predict phenomena and in designing multiple solutions to design problems.

- Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard).
 - Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
 - Identify the evidence that supports particular points in an explanation.
 - Apply scientific ideas to solve design problems.
 - Generate and compare multiple solutions to a problem based on well they meet the criteria and constraints of the design solution.
-

Practice 7 Engaging in Argument from Evidence ([^](#))

- *science, reasoning and argument based on evidence are essential in identifying the best explanation for a natural phenomenon.*
- *In engineering, reasoning and argument are needed to identify the best solution to a design problem.*
- *Student engagement in scientific argumentation is critical if students are to understand the culture in which scientists live, and how to apply science and engineering for the benefit of society.*
- *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 evaluate claims.*

Grades K - 12

- Construct their own explanations of phenomena using their knowledge of accepted scientific theory and linking it to models and evidence.
- Use primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon.
- Offer causal explanations appropriate to their level of scientific knowledge.
- Identify gaps or weaknesses in explanatory accounts (their own or those of others).

In their experience of engineering, students should have the opportunity to:

- Solve design problems by appropriately applying their scientific knowledge.
- Undertake design projects, engaging in all steps of the design cycle and producing a plan that meets specific design criteria.

- Construct a device or implement a design solution.
- Evaluate and critique competing design solutions based on jointly developed and agreed-on design criteria.

Grades K-2

- 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).
- Identify arguments that are supported by evidence.
- Distinguish between explanations that account for all gathered evidence and those that do not.
- Analyze why some evidence is relevant to a scientific question and some is not.
- Distinguish between opinions and evidence in one’s own explanations.
- Listen actively to arguments to indicate agreement or disagreement based on evidence, and/or to retell the main points of the argument.
- Construct an argument with evidence to support a claim.
- Make a claim about the effectiveness of an object, tool, or solution that is supported by relevant evidence.

Grades 3-5

- Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).
- Compare and refine arguments based on an evaluation of the evidence presented.
- Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation.
- Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.
- Construct and/or support an argument with evidence, data, and/or a model.
- Use data to evaluate claims about cause and effect.
- Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

Practice 8 Obtaining, Evaluating, and Communicating Information ([△](#))

- *Being able to read, interpret, and produce scientific and technical text are fundamental practices of science and engineering, as is the ability to communicate clearly and persuasively.*
- *Communicating information, evidence, and ideas can be done in multiple ways: using tables, diagrams, graphs, models, interactive displays, and equations as well as orally, in writing, and through extended discussions.*

Grades K - 12

- Use words, tables, diagrams, and graphs (whether in hard copy or electronically), as well as mathematical expressions, to communicate their understanding or to ask questions about a system under study
- Read scientific and engineering text, including tables, diagrams, and graphs, commensurate with their scientific knowledge and explain the key ideas being communicated.
- Recognize the major features of scientific and engineering writing and speaking and be able to produce written and illustrated text or oral presentations that communicate their own ideas and accomplishments.
- Engage in a critical reading of primary scientific literature (adapted for classroom use) or of media reports of science and discuss the validity and reliability of the data, hypotheses, and conclusions.

Grades K-2

- Obtaining, evaluating, and communicating information in K–2 builds on prior experiences and uses observations and texts to communicate new information.
- Read grade-appropriate texts and/or use media to obtain scientific and/or technical information to determine patterns in and/or evidence about the natural and designed world(s).
- Describe how specific images (e.g., a diagram showing how a machine works) support a scientific or engineering idea.
- Obtain information using various texts, text features (e.g., headings, tables of contents, glossaries, electronic menus, icons), and other media that will be useful in answering a scientific question and/or supporting a scientific claim.
- Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices, and/or design ideas.

Grades 3-5

- Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods.
- Read and comprehend grade- appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.
- Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices.
- Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices.
- Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.
- Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts.

References

Bell, P., Bricker, L., Tzou, Carrie, Lee., T., and Van Horne, K. (2012). Exploring the science framework; Engaging learners in science practices related to obtaining, evaluating, and communicating information. *Science Scope*, 36(3), 18-22.

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. (2012). *National Academies Press*.

1. [^] _^ *The NGSS' goal is to describe what students should be able to do, rather than how they should be taught.

- Students should learn these disciplinary core ideas in the context of science and engineering practices.
 - The future, science assessments will not assess students' understanding of core ideas separately from their abilities to use the practices of science and engineering.
 - They will be assessed together, showing students not only “know” science concepts; but also, students can use their understanding to investigate the natural world through the practices of science inquiry, or solve meaningful problems through the practices of engineering design."
 - We use the term “practices” instead of a term such as “skills” to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice. (NRC Framework, 2012, p. 30).
 - The practice of “planning and carrying out investigations” begins at the kindergarten level with guided situations in which students have assistance in identifying phenomena to be investigated, and how to observe, measure, and record outcomes.
 - By upper elementary school, students should be able to plan their own investigations. The nature of investigations that students should be able to plan and carry out is also expected to increase as students mature, including the complexity of questions to be studied, the ability to determine what kind of investigation is needed to answer different kinds of questions, whether or not variables need to be controlled and if so, which are most important,
- *The eight “practices are not separate; they intentionally overlap and interconnect and carrying out an investigation,” which in turn may lead to “analyzing and interpreting data.
- Engagement in practices is language intensive and requires students to participate in classroom science discourse.