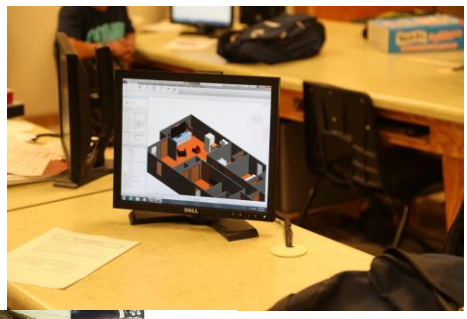
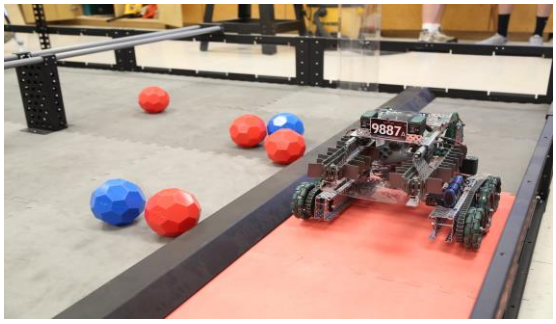
Science & Engineering Practices Support Guide for the South Carolina Academic Standards and Performance Indicators For Science


Molly M. Spearman
State Superintendent of Education

South Carolina Department of Education
Columbia, South Carolina

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SOUTH CAROLINA DEPARTMENT OF EDUCATION

The explication of the science and engineering practices included in this document were revised under the direction of Dr. Julie Fowler, Deputy Superintendent, Division of College and Career Readiness and Cathy Jones Stork, Interim Director, Office of Standards and Learning.

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SCIENCE AND ENGINEERING PRACTICES (SEPS): AN OVERVIEW

One of the most significant and fundamental shifts from the South Carolina Science Academic Standards (2005) to the South Carolina Academic Standards and Performance Indicators for Science (2014) is the incorporating of nine science and engineering practices (SEPs) with the content performance indicators in the form of *student* performance expectations. There is a very deliberate expectation of engaging in science content and concepts through the use of the science and engineering practices, both as a means of developing understanding of these concepts as well as a means of demonstrating that understanding. By comparison, the 2005 science standards employed verbs from the revised Bloom's taxonomy as performance expectations that were primarily focused on conveying relatively straight forward details about specific science content with no clear expectation of how those concepts were to be developed or represented through scientific practices and skills.

Science and engineering practices represent what scientists and engineers do as a matter of routine and illustrate how scientific knowledge and concepts develop through asking questions and conducting investigation, obtaining and analyzing data, constructing explanations, arguing claims supported by evidence, and communicating and evaluating information. They also describe how needs and problems are addressed through the design process that designs, constructs, tests, evaluates, and refines solutions.

Science is the study of the universe and all of its contained phenomena. Engineering is the way we fulfill human needs and solve problems. These practices represent the skills and knowledge necessary for scientists and engineers to accomplish what they do.

Scientific practices start with questioning that leads to inquiry, seeking evidence to ultimately construct explanations and develop models that can be used to best describe and predict (at the present) how and why natural phenomena occur.

Engineering practices start with defining problems and identifying human needs; this process leads to designing, testing, and refining solutions in order to accumulate evidence necessary to determine the best possible solution (at the present) for the perceived need or problem.

The practices common to all areas of science and engineering are:

- Asking questions
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations
- Engaging in scientific argument from evidence
- Obtaining, evaluating, and communicating information
- Constructing devices or designing solutions.

The Role of Evidence

Evidence is a common theme throughout the application of the science and engineering practices.

- Ask Questions, Define Problems, Plan and Carry out Investigations, Use Models: *Acquiring evidence.*
- Analyze and Interpret Data and Mathematics and Computational Thinking: *Making meaning of the evidence.*
- Engage in Argument, Construct Explanations, Design Solutions, Develop Models: *Using evidence to support claims.*
- Obtain, Evaluate, and Communicate Information, Use Models: *Providing context for the evidence as well as communicating the outcomes supported by the evidence*.

In science, evidence is used to support claims and explanations. In engineering, evidence is used to assess and evaluate solutions.

Shifting from the South Carolina Science Academic Standards (2005), which relied on students developing the capacity to explain, summarize, illustrate, identify, exemplify, compare, etc. scientific concepts, the South Carolina Standards and Performance Indicators for Science (2014) focus on *engaging in the practices of science and engineering as a means to develop understandings of scientific concepts*. This is accomplished primarily through the use of evidence. Throughout the standards, at all grade levels, students are charged with acquiring evidence through investigation, testing, model use, and research as a means of constructing scientific explanations, supporting scientific claims through argumentation, refining and proposing design solutions to problems, communicating scientific concepts, and developing reliable models of natural phenomena.

Gathering, Reasoning, and Communicating Information

Another way to look at the organization of the science and engineering practices is through the lens of Gathering Information, Reasoning with Information, and Communicating Information[1]. In this context, information is not limited to scientific informational texts but also includes data, both observational and measured, as well as claims, explanations, and models supported and developed using evidence.

- Gathering:
  - Obtain Information
  - Ask Questions
  - Define Problems
  - Plan and Carry Out Investigations
  - Use Models to Gather Data
  - Use Mathematics and Computational Thinking
- Reasoning:
  - Evaluate Information

    - Analyze Data
    - Use Mathematics and Computational Thinking
    - Construct Explanations
    - Design Solutions
    - Develop Scientific Arguments from Evidence
    - Use Models to Predict and Develop Evidence
- Communicating:
    - Communicate Information
    - Supporting Claims from Evidence through Argumentation
    - Use Models to Communicate

[1] from *CSSS Session: A Vision for Science Education: The Integration of the NGSS Practices in Classroom Instruction*, Brett Moulding, Peter McLaren, NSTA 2014 National Conference, Boston, MA

Practices as Performance Expectations

As defined by the performance indicators of the standards, the science and engineering practices serve to identify performance expectations that our students will demonstrate in the context of disciplinary core content ideas. Not only will these practices serve as a means by which students will develop scientific conceptual understandings, but they will also function as the means by which students will demonstrate these understandings in an authentic manner. These practices should be used to drive the instructional design of learning experiences in such a way as to guide students to develop the capacity to perform these science and engineering practices as part of the process of developing an understanding of scientific concepts.

The practices also serve to drive assessment as teachers are tasked with not only assessing conceptual understandings related to content but also assessing the degree to which their students are able to meet the performance expectations of the different scientific and engineering practices (scaled appropriately for the age and grade of the student).

The Interconnected Nature of the Practices

It is important that teachers realize that the eight science and engineering practices are not intended to be used in isolation. Even if a performance indicator for a given standard only lists one of the practices as a performance expectation, scientists and engineers do not use these practices in isolation but rather as part of an overall sequence of practice. When educators design the learning for their students, it is important that they see how a given performance expectation fits into the broader context of the other science and engineering practices. This will allow teachers to provide comprehensive, authentic learning experiences through which students will develop and demonstrate a deep understanding of scientific concepts. One way to consider this relationship is presented in Figure 1.

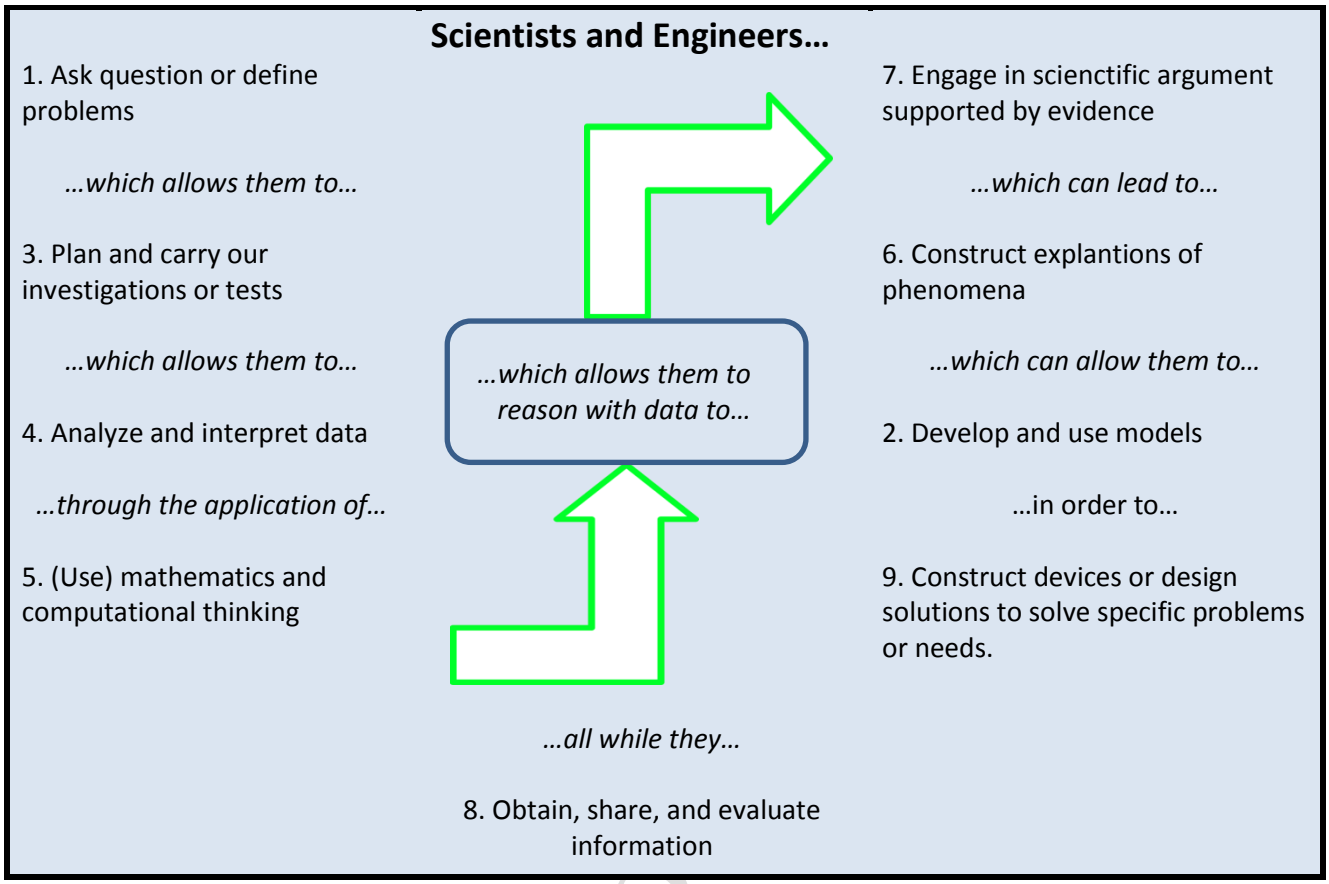


Figure 1: Interconnected nature of the science and engineering practices.

It must be noted that this is not the only way this relationship can be structured. For example, models can be used to generate data or as a source of information that can provide context for an investigation. Questions can be asked not only as a precursor to an investigation but as a result of the outcomes of an investigation.

Format of the Science and Engineering Practices Standard

At the beginning of each grade level standard, there is a science and engineering practices standard that serves to define the role of the science and engineering practices in the broader context of developing an understanding of science concepts, developing scientific thinking habits of mind, and engaging in science in a manner consistent with work done by scientists and engineers. This standard is followed by a pair of conceptual understandings which represent what concepts, understandings and core disciplinary ideas the teachers should be looking for evidence of when assessing their students in terms of overall capacity to perform as scientists and engineers.

For example,

- **Standard 5.S.1:** The student will use the science and engineering practices, including the processes and skills of scientific inquiry, to develop understandings of science content.

- **5.S.1A. Conceptual Understanding:** The practices of science and engineering support the development of science concepts, develop the habits of mind that are necessary for scientific thinking, and allow students to engage in science in ways that are similar to those used by scientists and engineers.

- **5.S.1B. Conceptual Understanding:** Technology is any modification to the natural world created to fulfill the wants and needs of humans. The engineering design process involves a series of iterative steps used to solve a problem and often leads to the development of a new or improved technology.

While this example comes from the 5th grade standards, it is the same in all grades and subjects.

Each of these conceptual understandings is followed by one or more performance indicators that serve to functionally define the performance expectations for each of the nine practices in terms of how they are integrated into the content-specific performance indicators that follow and what sort of tasks students will be expected to perform to develop the scientific conceptual understandings for each content strand as well as how they will be expected show evidence of that conceptual understanding through the use of each practice.

INTEGRATION, NOT ISOLATION

It is important to note that although the science and engineering practices are defined by a separate academic standard, teachers should not teach these performance indicators on their own, disconnected from scientific concepts and content:

"It is critical that educators understand that the science and engineering practices are not to be taught in isolation. There should not be a distinct "Inquiry" unit at the beginning of each school year. Rather, the practices need to be employed within the content for each grade level or course. Students should engage in scientific and engineering practices as a means to learn about the specific topics identified for their grade levels and courses." (p. 3)

This statement from the standards document communicates not only the expectations that these performance indicators are *not* to be treated as a separate unit of study, but also that it will be through these practices that students come to develop the conceptual understandings identified in each subsequent content strand. The science and engineering practices are not simply a means of validating content information and expected outcomes through lecture, direct instruction, and/or scripted labs and activities. Rather, students will learn science *through the application and use* of the science and engineering practices embedded within each set of content performance indicators.

FORMAT OF SEPS SUPPORT DOCUMENT

The format of this document is designed to be structurally uniformed for each of the science and engineering practices. For each, you will find the following sections--

- **Grade Level Progressions**
  - This section includes a chart of the specific science and engineering practice indicators within each grade band.

- **Specific Changes Per Grade**
  - This section highlights each change as the indicator progresses and becomes increasingly complex. Specific differences are noted in italics.
- **Defining Characteristics**
  - This section provides an overview of the defining characteristics of the science and engineering practice indicator in order provide a deeper conceptual understanding of the purpose and function of the practice and its role in science and engineering disciplines.
- **Instructional Guidance and Considerations**
  - This section provides guidelines for educators on how to use the science and engineering practice indicator as a performance expectation in a learning experience.
- **Evidence of Mastery**
  - This section provides a list of evidence of student success factors that educators can use when assessing a student's performance through the lens of the science and engineering practice indicator.
- **Connections with Other Science and Engineering Practices**
  - This section illustrates connections between the specific science and engineering practice indicator and the other eight science and engineering practices to provide educators with guidance on integrating multiple practices throughout the learning experience.
- **Performance Task Examples**
  - This section provides a chart of several grade-band examples of performance tasks related to science content standards and indicators that reflect the specific science and engineering practice indicators as performance expectations. This section also provides corresponding examples of performance tasks that do not meet the criteria of performance expectations for the given science and engineering practice.

SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1A.1: ASK QUESTIONS

GRADE LEVEL PROGRESSIONS

K.S.1A.1 **1.S.1A.1** **2.S.1A.1**	Ask and answer questions about the natural world using explorations, observations, or structured investigations.
3.S.1A.1 **4.S.1A.1**	Ask questions that can be (1) answered using scientific investigations or (2) used to refine models, explanations, or designs.
5.S.1A.1	Ask questions to (1) generate hypotheses for scientific investigations or (2) refine models, explanations, or designs.
6.S.1A.1 **7.S.1A.1** **8.S.1A.1**	Ask questions to (1) generate hypotheses for scientific investigations, (2) refine models, explanations, or designs, or (3) extend the results of investigations or challenge claims.
H.B.1A.1 **H.C.1A.1** **H.P.1A.1** **H.E.1A.1**	Ask questions to (1) generate hypotheses for scientific investigations, (2) refine models, explanations, or designs, or (3) extend the results of investigations or challenge scientific arguments or claims.

SPECIFIC CHANGES PER GRADE

- In grades K-2, performance expectations include *asking and answering questions* through explorations, observations, and investigations.
- Starting in grade 3, performance expectations expand to include asking questions that will be *answered through investigations* or are *used to refine models, explanations, or designs*.
- The concept of a *scientific hypothesis* is introduced in grade 5.
- Starting in grade 6, performance expectations expand to include asking questions *based on the results of investigations*.
- Starting in grade 6, performance expectations expand to include asking questions to *challenge claims*.
- Starting in grade 9, performance expectations expand to include asking questions to *challenge scientific arguments*.

DEFINING CHARACTERISTICS

Questions drive science and engineering. It is an essential practice to developing scientific habits of mind. These questions are driven by curiosity, by the desire to understand a phenomenon, or by the need to solve a problem. Asking *real* questions and defining *real* problems are not done for their own sake. In science, a question should always lead to an investigation to acquire the necessary evidence in an attempt to answer that question. In engineering, defining the problem should always lead to the designing and testing of a solution to that problem.

- Science begins with questions about phenomena, seeking to gather the evidence necessary to construct an explanation about the phenomena. Asking questions leads towards inquiry.
- Engineering begins with a problem, need, or desire and seeks to develop and test a solution to solve the problem, meet the need, or fulfill the desire. Defining problems leads towards design.

Scientific vs. Non-scientific questions

- Scientific questions can be addressed through quantifiable data. These data are reproducible through carrying out investigations and should be consistent across trials. This process leads towards a scientific explanation that is well supported by evidence from the data.
- Non-scientific questions do not lend themselves to the collection of quantifiable data or simply cannot be addressed through a structured, scientific investigation. In the case of the former, they cannot be answered through the acquisition of data that is reproducible across investigations. Answers to these questions will not be consistent because the data will not be consistent.

The kinds of questions scientists ask

- What exists and what happens?
- What causes it to happen?
- How does one know?
- What constitutes data?
- How can information (evidence, explanations, and models) about this phenomenon be communicated?

The kind of questions engineers ask

- What can be done to address this particular need or want?
- How can the need be better specified (criteria for success, constraints, what should be tested)?
- Why does this need exist?
- What tools and technologies are available or could be developed for addressing this need?
- How can the solution to the need be communicated?

The goals for this practice are for students to generate questions about phenomena, to distinguish scientific from non-scientific questions, to formulate and refine questions that can be tested, to

probe the premises of arguments, to identify needs and desires behind an engineering problem, and to define constraints and specifications for a solution.

INSTRUCTIONAL GUIDANCE AND CONSIDERATIONS

The best questions and problems are those posed or defined by the students. Questions can emerge in a variety of ways:

- Curiosity about some witnessed phenomena
- Prompted by sources of information (readings, videos, visuals, etc...)
- Inspired by explanatory models and theories of phenomena (making predictions, refining, revising, and applying existing models and theories)
- Answers to questions can lead to more questions
- Seeking different ways to solve a problem

Strategies for generating questions

- Engage in discussion around phenomena (can be familiar or novel)
- Categorize and distinguish questions into groups
- Distinguish between scientific and non-scientific questions
- Identify the purpose behind the questions (questions are not just for their own sake)

Brainstorming variables to generate questions

- In groups, brainstorm different things that affect the phenomenon you are learning about.
- Use this list to narrow down a single variable that can be investigated. (The rest of the items on your list become your controls in the investigation).
- Pose a researchable question related to the variable.
- Identify what you are testing (the independent variable) and what you plan to measure (the dependent variable).
- If your question contains both the thing you are testing and the thing you plan to measure, you have generated a testable question!

Strategies for defining problems

- Discuss a real or hypothetical scenario that needs to be addressed.
- Brainstorm possible constraints, challenges, concerns, and circumstances that might influence or limit the possible design of a solution or device.
- Use brainstorming to define a specific problem to be addressed.
- Make a list of what is already known about the problem and what still needs to be learned.
- Identify how a successful solution to the problem might look and how success will be measured.

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Ask scientific questions. Scientific questions are questions about natural phenomena and/or processes that can be answered through scientific investigations and experimentations.
- Ask scientific questions that reflect or are based upon scientific information. Scientific information can include scientific informational texts and media, data from observations and measurements, models, natural phenomena and processes.
- Distinguish between scientific and non-scientific questions.
- Ask questions about authentic human needs and problems that will lead to designing solutions.
- Ask questions about the parameters related to human problems and needs.

CONNECTIONS WITH OTHER SCIENCE AND ENGINEERING PRACTICES

- Plan and Carry Out Investigations (S.1A.3)
    - The questions and problems define the purpose behind any investigation, whether it is to seek an answer to the question or to test a solution to a problem.
- Analyze and Interpret Data (S.1A.4) and Use Mathematics and Computations Thinking (S.1A.5)
    - Evidence and data acquired through investigation are analyzed and interpreted in order to construct an explanation that serves as an answer to the questions or to see if the proposed solution being tested is an effective solution to the problem.
- Engage in Argument from Evidence (S.1A.7) and Construct Explanations (S.1A.6)
    - Claims argued with acquired evidence are where possible answers or solutions are proposed, debated, and evaluated. Explanations and solutions arise when claims are vetted and stand up to being evaluated through the argumentation process. In either case, they serve as proposed and accepted answers to the initial questions and solutions to the initial problems.
- Obtain, Evaluate, and Communicate Information (S.1A.8) and Develop and Use Models (S.1A.2)
    - Information and models can serve to put questions into the context of the science content. They can also serve as a way to develop the necessary prior knowledge from which questions and problems can be proposed.
- Construct Devices or Design Solutions (S.1B.1)
    - Engineers identify problems in much the same was that scientists ask questions. Instead of leading to investigations, problems lead to the development and testing of solutions.

PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples is to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non Example
K-2	Life Science	Students observe pill bugs for a given time period and are prompted to generate questions based on their observation of the pill bugs' behavior.	Teacher provides a set of questions for students to answer about pill bugs.
3-4	Earth Science	Students generate questions about water's effect on land forms prior to an investigation. They generate additional questions based on information gained through that investigation to refine models and understandings.	Teacher provides information on water's effect on landforms and has students answer teacher provided questions.
5	Physical Science	Students generate questions, allowing them to make predictions about the relationships between different variables and solution rates.	Teacher directs students to conduct an investigation verifying that table salt dissolves faster in hot water than in cold water.
6	Life Science	Students conduct an investigation to determine the environmental factors that affect the development of flowering plants. Students use the data from the investigation to further question how those variables have different effects on plants.	Teacher provides scripted labs to test variables.
8	Physical Science	Students, when presented with the claim that waves transmit energy, generate questions that challenge that claim.	Teacher provides multiple examples of how waves transmit energy and provides a scripted lab to reinforce that waves transmit energy.
High School	Biology	Students generate questions to evaluate quantitative data regarding the effects of greenhouse gas on the carbon cycle and global climate change.	Teacher presents conclusion from data about the effects of greenhouse gases on the carbon cycle and global climate change.
High	Chemistry	Students plan and conduct a controlled	Students conduct a

School		scientific investigation that generates mathematical data illustrating how mass is conserved in a chemical reaction. Students may use the outcome of the investigation to generate additional questions about different chemical reactions and how mass is conserved in those scenarios.	teacher-designed lab that verifies expected outcomes concerning the law of conservation of mass.

SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1A.2: DEVELOP AND USE MODELS

GRADE LEVEL PROGRESSIONS

K.S.1A.2 **1.S.1A.2** **2.S.1A.2** **3.S.1A.2** **4.S.1A.2** **5.S.1A.2** **6.S.1A.2** **7.S.1A.2** **8.S.1A.2** **H.B.1A.2** **H.C.1A.2** **H.P.1A.2** **H.E.1A.2**	Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others.

SPECIFIC CHANGES PER GRADE

- There are no changes in performance expectations between grade levels for students to develop and use models.

DEFINING CHARACTERISTICS

Scientists use models to represent simple and complex phenomena, systems, and processes, as well as to communicate these concepts to others. In engineering, models are used to analyze existing systems to look for flaws or test solutions and to visualize designs and communicate them to others. Whereas an individual's mental model is a personalized way of conceptualizing a process or phenomenon, scientific models are conceptual models that serve as mechanisms for communicating information about processes or phenomena; that is, they are coherent and consistent, they can be shared with others, they are external, and they serve as analogs for processes and phenomena. And while scientists and engineers use mental models as part of the process of reasoning and testing, they use scientific models to communicate in a clear, unambiguous way. Both scientists and engineers, however, must be aware of the inherent limitations in using models to describe and communicate natural phenomena and artificial designs.

Types of models

- Structural: describing the physical arrangement of something
- Behavioral: describing the performances or actions of something

- Functional: describing how something works

Models can be--

- Simple diagrams
- Constructs
- Computer generated
- Analogies (comparing something complex with something more easily understood)
- Mathematical formulae
- Simulations of actions

In engineering, models can be used to build and test designs.

Model practice elements:

- Developing a model that embodies aspects of a theory and evidence
- Evaluating the model against empirical evidence and theory
- Using the model to illustrate, predict, and/or explain
- Revising that model to better fit evidence

What a model is not:

- An art project or construct for the sake of the construct itself (models should be used to learn or communicate science content)
- Descriptive only (models predict, explain, and help answer "how" or "why" questions)
- An all-inclusive interpretation or explanation (they may be subject to revision with more evidence or perhaps be limited by the type of model)

The goals for this practice are for students to construct 2-D drawings/diagrams and 3-D models that represent events or systems, to represent and explain phenomena through a variety of models, to discuss the limitations of precision of models, to use simulations to investigate, and to make and use models to test and compare the effectiveness of designs.

INSTRUCTIONAL GUIDANCE AND CONSIDERATIONS

Developing models as a part of instructional design

- Main question originating from some natural phenomena
- Develop an initial model to attempt to answer that question
- Conduct investigations to gather data as a means to assess and refine the initial model
- Critically examine evidence and ideas in the context of their model
- Evaluate models and ideas and develop a consensus model
- Apply the model to answer the initial question

Strategies for effectively developing and using models in the classroom.

- Include a driving question that addresses an important idea and provides coherence in the unit
- Models target how things happen, how they work, and why they work
- Focus on natural phenomena and data/observations from those phenomena
- Engage students in cycles of model evaluation and revision

- Models are based on empirical data and evidence
- Require students to use their models to explain natural phenomena
- Engage in the social nature of modeling (arguing from evidence, consensus building, application)
- Don't give them "the answer"
- Don't tell them their models are "wrong." Use questions to guide the process and their understanding

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Develop models from sources of evidence and scientific information. This means they should be able to use information (obtained through research or investigations) about some process or natural phenomena to develop and construct a functional, descriptive model that represents the process or phenomenon. This is not simply copying a pre-existing model from some source.
- Use models to communicate information about some natural phenomenon or process (cause and effect relationships, sequences, details, etc…).
- Use models to communicate a proposed and/or tested design or solution to a need or problem.
- Use models to test different variables of a natural process/phenomenon or solution/design.

CONNECTIONS WITH OTHER SCIENCE AND ENGINEERING PRACTICES

- Ask Questions (S.1A.1) and Plan and Carry Out Investigations (S.1A.3)
    - The use of models can serve as a source of prior knowledge for framing questions and problems as well as helping plan and conduct scientifically sound investigations and tests. Models may also serve as a way to answer scientific questions. The process of developing models may be the ultimately outcome of a question or problem and its subsequent investigation.
- Analyze and Interpret Data (S.1A.4) and Use Mathematics and Computational Thinking (S.1A.5)
    - Models may be applied to the analysis of data in an effort to apply scientific concepts to interpretation of the data. Mathematical models may also be a part of the analysis process. Analyzed data may serve as evidence that leads towards the development of a model to explain some process or phenomenon.
- Engage in Argument from Evidence (S.1A.7) and Construct Explanations (S.1A.6)
    - The process of argumentation and constructing explanations can lead to the development of models that are used as a way to communicate the concepts, processes, and phenomena that the evidence supports. Applying and using scientific models can also provide content context to the processes of argumentation and constructing explanations or designing effective solutions.
- Obtain, Evaluate, and Communicate Information (S.1A.8)
    - Models can be one source of information that students find and evaluate. Content information can also be applied in the processes of developing models to explain phenomena and/or processes.

- Construct Devices or Design Solutions (S.1B.1)
    - Engineers use models as a way of both communicating successful designs as well as a way to test designs or solutions when it is impractical to create a full-scale functioning design or solution to a problem or need.

PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples is to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non-Example
K-2	Earth Science	Students conduct a series of observations to identify the effect of moving air on objects. Students develop visual models to communicate the cause and effect relationship between moving air and objects.	Students copy an existing model.
3-4	Astronomy	When presented with a traditional, visual model of the solar system, students evaluate and refine the model based on research to include the order, position, and composition of the plants.	Students provide a simple visual model based on an existing example.
7	Life Science	Students develop and use a model of a cell to communicate what occurs when an organelle fails.	Students construct a visual, labeled model of a cell from their notes.
High School	Physics	Given a claim that there is a relationship between electrical currents and magnetic fields, students are provided materials to conduct investigations to determine the exact nature of the relationship between electrical currents and magnetic fields and develop a model that they use to illustrate the relationship.	Students copy an existing model of magnetic fields.

SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1A.3: PLAN AND CARRY OUT INVESTIGATIONS

GRADE LEVEL PROGRESSIONS

K.S.1A.3	With teacher guidance, conduct structured investigations to answer scientific questions, test predictions and develop explanations: (1) predict possible outcomes, (2) identify materials and follow procedures, (3) use appropriate tools or instruments to make qualitative observations and take nonstandard measurements, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
1.S.1A.3 **2.S.1A.3**	With teacher guidance, conduct structured investigations to answer scientific questions, test predictions and develop explanations: (1) predict possible outcomes, (2) identify materials and follow procedures, (3) use appropriate tools or instruments to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
3.S.1A.3 **4.S.1A.3**	Plan and conduct scientific investigations to answer questions, test predictions and develop explanations: (1) formulate scientific questions and predict possible outcomes, (2) identify materials, procedures, and variables, (3) select and use appropriate tools or instruments to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
5.S.1A.3	Plan and conduct controlled scientific investigations to answer questions, test hypotheses and predictions, and develop explanations: (1) formulate scientific questions and testable hypotheses, (2) identify materials, procedures, and variables, (3) select and use appropriate tools or instruments to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
6.S.1A.3 **7.S.1A.3** **8.S.1A.3**	Plan and conduct controlled scientific investigations to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses, (2) identify materials, procedures, and variables, (3) select and use appropriate tools or instruments to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
H.B.1A.3 **H.C.1A.3** **H.P.1A.3** **H.E.1A.3**	Plan and conduct controlled scientific investigations to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.

SPECIFIC CHANGES PER GRADE

- In grades K-2, performance expectations include conducting structured scientific investigations *with teacher guidance*.
    - In this context, structured scientific investigations mean investigations that are guided by the teacher but still conducted by students in order to answer a scientifically testable question that can be answered through objective investigation, experimentation, and observation.
- In kindergarten, students make qualitative observations and use *non-standard measurements* as sources of data.
- Starting in grade 1, performance expectations expand to include making *qualitative measurements* using appropriate tools. Students should no longer be making non-standard measurements.
- Starting in grade 3, performance expectations expand to *planning and carrying out scientific investigations*.
    - In this context, scientific investigations and questions serve to distinguish from structured investigations. Students are now expected to plan and carry out (without as much direct teacher guidance) investigations designed to answer scientifically testable questions.
- Starting in grade 3, performance expectations expand to include *formulating scientific questions*.
- Starting in grade 3, performance expectations expand to include *identifying variables*.
- Starting in grade 3, performance expectations expand to include *selecting* the appropriate tools they will use to carry out scientific investigations
- Starting in grade 5, performance expectations expand to include formulating *testable hypotheses*.
    - In this context, the term testable hypothesis serves to distinguish the expectation from predicting possible outcomes. Students formulate testable hypotheses not only as prediction of possible outcomes but also as proposed explanations for possible that can then be tested through experimentation and investigation.
- Starting in grade 9, performance expectations expand to include formulating scientific questions and testable hypotheses based on *credible scientific information*.
    - In this context, credible scientific information refers to sources of information that have been evaluated and are considered scientifically valid and accurate.

DEFINING CHARACTERISTICS

Scientists and engineers investigate the world with two goals - to answer questions and to develop and test designs, theories, and explanations about how the world works. This includes engaging in careful observation and description of natural phenomena as well as the ability to design experimental inquiries to test a hypothesis and answer a question. Investigations generate data that is then analyzed. To do this, scientists and engineers need to carefully identify parameters to be controlled during an investigation, what tools will be necessary to conduct measurements, and what variables are to be tested and measured to generate the evidence necessary to determine the conclusions of the investigation.

In science, the goal of carrying out investigations is to acquire data that can be used to refine theories and ideas about natural phenomena. In engineering, investigations provide data that can be used to test the effectiveness of and refine designs and solutions.

Investigations can be designed to:

- Generate data (observations/measurements) that can be used to generate a hypothesis.
- Test an existing hypothesis.
- Isolate variables to determine how they impact a phenomenon.
- Test design solutions.

Reproducible Data

Scientific investigations generate consistent, reproducible data and observations.

- Procedures are clear and complete.
- Tools and materials are appropriate to the task.
- Precision (how close you are to the target) and accuracy (how often do you hit the same area) are attended to.
- Outside variables are controlled as much as possible.

Importance of Sample Size

Reliability in the outcome of the investigation comes from having a sufficient body of data to serve as evidence. Scientific claims cannot be argued with only a single or limited body of data to serve as evidence. When multiple trials produce consistent, reproducible results, then it is possible to use that data as evidence to support claims and, ultimately, construct explanations.

It is essential for students to know that for an investigation to be scientifically valid, replication within the procedures is important to verify the results and produce valid conclusions. Scientists want to report true results; therefore, they conduct repeated trials so that patterns or trends in the data can be determined. The more data that is collected through replication, the more reliable the results. Without replication, errors in procedures or data collection may not be detected.

While gathering data during an experiment:

- Data needs to be gathered more than one time under the same conditions and with the same measurement tools.
- Repetition ensures that the experiment is valid and that the data is reliable. Validity indicates how close the investigation is to being accurate and dependable. As a result of validity, other investigations repeated the same way should produce similar results.
- When possible, measurements should be taken several times, and then the results averaged.
- Each set of repeated data is called a trial.

An investigation may involve a sample, or a portion of the total number, as a type of estimation.

- The sample is used to take a representative portion of the objects or population for research.
- A poorly chosen sample size can be unrepresentative of the whole.

- Careful observations made from a proper sample size or manipulating variables within that sample size result in information and conclusions that might apply to the whole population.

The "lifecycle" of data

Investigation leading to data collection → data interpreted and evaluated to be used as evidence → evidence used to develop and refine models, arguments, and theories → new questions generated, cycle repeats.

The goals for this practice are for students to formulate questions that can lead towards the framing of a hypothesis that can be tested, to decide what and how much data is necessary, what tools are needed, and how the measurements will be recorded, to plan and conduct investigations, to identify independent and dependent variables, as well as what parameters need to be controlled, and to evaluate the effectiveness of the investigation's design.

Scientific Tools

Students need to know that different tools are needed to collect different kinds of data. Students should be able to use tools from previous grade levels that are appropriate to the content of their current grade level.

K	1. A magnifier, or hand lens, is a science tool that can be used to see details of objects that are too small to be seen clearly with unaided eyes. o A magnifier should be held between the eye and the object being viewed. o The magnifier should be moved back and forth until the object looks clear. o Magnifiers can be used to observe physical properties of objects. Eyedroppers are short tubes fitted with rubber bulbs at the top of the tube that are used to measure liquids by drops when gathering specific data. o Squeeze the bulb before inserting it into the liquid to obtain some of the liquid. o Eyedroppers can be used to add small amounts of liquids.
1	Standard English units should be used where appropriate when making measurements of objects. For example, rulers should measure to the nearest whole inch; time can be measured in hours to the nearest half hour. A ruler is a measurement tool that can be used to measure the length, width, or height of an object or the distance between two objects. o When using a ruler, make sure to begin measuring from the zero (0) mark, not necessarily the edge of the ruler.
2	A thermometer is a tool that measures temperature. o When using a thermometer, make sure not to place the bulb of the thermometer on the bottom or sides of the container or touch the bulb when taking air temperature. o When reading the temperature on a thermometer, it should be vertical and at eye level with the top of the liquid in the glass tube.

	o A thermometer measures temperature in degrees Fahrenheit (^{o}F) and Celsius (^{o}C) to the nearest degree. NOTE: Fahrenheit will be used to measure weather data only. All other temperature readings will be taken using the Celsius scale. Use only thermometers with colored alcohol in them (such as red or blue), NEVER mercury thermometers (silver liquid in them). A rain gauge is a tool that measures the amount of rainfall. o To collect rainfall accurately, the rain gauge must be in an open area. o To read the rain gauge, hold it at eye level. o A rain gauge measures the amount of rainfall in inches (in). A balance is a tool that measures the mass of an object compared to a known mass. Mass is the amount of matter, or material, in an object. o When using a pan or bucket balance, be sure the balance pointer begins at zero (is level). o Place the object being measured on one side. o Place the known masses on the opposite side until the balance is level and the pointer is again at zero. o When the balance is level, the mass of the object is equal to the total of the known masses. o A balance measures the mass of an object in grams (g). A measuring cup is a tool that measures volume. o To read the measuring cup, place the cup on a level surface. o When using the measuring cup to measure volume of a solid, be sure the top surface of the solid is level. o A measuring cup measures volume in fluid ounces (oz), parts of a cup (c), milliliters (mL), or liters (L).
3	A beaker is a tool that measures liquid volume. o To read the volume of a liquid in a beaker, place the tool on a level surface. o When using a beaker to measure the volume of a granular (powdered) solid, be sure the top surface of the solid is level. o Choose the appropriate size beaker for the measurement task—use small beakers for measuring small amounts, and large beakers for large amounts. o A beaker measures the volume in metric units such as milliliters (mL) or liters (L). A meter tape, or meter stick, is a measurement tool that can be used to measure the length, width, or height of an object or the distance between two objects. o When using a meter tape, or stick, make sure to begin measuring from the zero (0) mark, not necessarily the edge of the tool. o A meter tape, or stick, measures in metric units such as centimeters (cm) or meters (m). Forceps/tweezers are tools that grasp or pick up small materials. A graduated cylinder is a tool that measures volume of liquids.

	o To read the graduated cylinder, place the tool on a level surface. o Choose the right size graduated cylinder for the measurement task—use small graduated cylinder for measuring small amounts, and large graduated cylinder for large amounts. o The graduated marks are in metric units such as milliliters (mL). A graduated syringe is a tool that measures volume of liquids. o Place the end of the syringe in the liquid and then pull the plunger out to draw in the appropriate amount of liquid. o A graduated syringe measures in metric units such as milliliters (mL). It is also essential for students to use tools such as rulers (measuring to millimeters), pan balances (measuring in grams), or measuring cups (measuring in parts of a cup).
4	A tuning fork is a tool that produces vibrations when struck appropriately. o Use the rubber mallet or rubber surface to strike the tuning fork. A compass is a tool that is used to determine the cardinal directions of North, South, East, and West when using a wind vane to identify wind direction. An anemometer is a weather instrument used to determine wind speed. o An anemometer should be vertical and needs to be able to spin without obstruction. o An anemometer measures wind speed in miles per hour (mph). A mirror (plane/flat) is a tool that reflects light toward a given direction. A prism is a tool that breaks light into the colors of the spectrum. o To use a prism appropriately, the light has to enter the prism at the correct angle to the surface in order to separate the white light. It is also essential for students to use tools such as rain gauges (measuring in inches), and beakers or graduated cylinders (measuring to milliliters or liters). Other units of measurement that students should be familiar with are kilograms (mass) or kilometers (distance).
5	A timing device is an instrument used to measure time. o An example of a timing device is a stop watch or clock with a second hand. o Time is measured in seconds (s), minutes (min), hours (hr), and days. A 10x magnifier is a tool that is used to enlarge objects or see details. o Objects seen through a 10x magnifier look ten times larger than they do with the unaided eye. It is also essential for students to use tools such as graduated cylinders and syringes (measuring in milliliters).
6	A spring scale is a tool used to measure the weight of an object or the force on an object.

	o Some spring scales have a slider that moves in response to the weight/force of an object. The measurement is read on one of two scales located on either side of the slider. o Some spring scales have a spring that is visible through a clear plastic tube with two scales labeled on either side of the tube. o Before an object is attached to the spring scale, make sure the marker is on the zero (0) by adjusting the slider or knob usually found on the top of the scale. o A spring scale measures weight or force in newtons (N). A digital balance is a tool used to measure the mass of an object. A barometer is an instrument used to measure air pressure or a change in pressure readings. o Many of the barometers have qualitative descriptions of weather conditions associated with air pressure but this alone should not be used to forecast weather. o To read your barometer, first tap the glass lightly, but firmly, to ensure that the reading pointer attached to the linkage mechanism inside the barometer is not sticking. o The other pointer that is found on most instruments is the set pointer and is usually made of brass. o The set pointer can be turned by means of the knob at the center of the glass so that it covers the reading pointer. If the reading pointer has moved between readings then it can be determined that the pressure is now lower or higher and by how much. o A barometer scale is measured in millimeters or inches of mercury or millibars (mb). A sling psychrometer is a tool used to measure relative humidity. o A sling psychrometer is made of two thermometers—a wet bulb and a dry bulb—held together by a handle. o The wet bulb thermometer is covered with a piece of cloth and moistened. o The two thermometers are then moved through the air. After a period of time the temperature of each thermometer is recorded. A relative humidity chart is used to determine the relative humidity percent. It is also essential for students to use tools such as graduated cylinders (measuring at the meniscus to milliliters), graduated syringes (measuring to milliliters), anemometers (measuring in miles per hour), compasses, 10x magnifiers, or timing devices (measuring in minutes or seconds) to gather data. NOTE: All temperature readings during investigations will be taken using the Celsius scale unless the data refers to weather when the Fahrenheit scale is used.
7	A microscope is a tool that is used to magnify the features of an object. A compound microscope has two or more lenses. Other parts of a compound microscope are: Eyepiece—contains the 10X magnifying lens Coarse adjustment knob/focus—focuses the image under low power Fine adjustment knob/focus—focuses the image under high power Objective lenses—two or three separate lenses that contain varying powers of magnifying lenses

	Stage and stage clips—supports and hold the microscope slide in place while viewing Diaphragm—controls the amount of light available Light source—a mirror, external or internal light source that shines light through the object being viewed Arm—supports the body tube which connects the eyepiece to the set of objective lenses Base—supports the microscope It is essential for students to use the microscope safely and accurately. When looking through a microscope, the lighted area is the field of view. Adjust the diaphragm until an adequate amount of light is available. o To make the field of view brighter, open the diaphragm. o To make the field of view darker, close the diaphragm. To view an object under the microscope, first focus on the lowest power objective lens. Then change to the highest power objective lens if necessary. When focusing the image under low power objective, use the coarse adjustment knob. Use only the fine adjustment knob to sharpen the focus when using the high power objective. To calculate the magnification of objects seen through a microscope, multiply the magnification of the eyepiece times the magnification of the objective lens being used. Objects on the slide move in the opposite direction when being viewed through the eyepiece (for example, if the slide is moved to the left, the object being viewed appears to move to the right). It is essential for students to use care when handling the microscope. A microscope should be held and carried with one hand under the base and one hand on the arm. Some microscopes may have a mirror as the light source. Care should be taken not to aim the mirror directly at the Sun. It is also essential for students to use tools such as magnifiers (hand lenses), 10X magnifiers, or beam balances (measuring to centigrams) to gather data.
8	Convex lenses are tools used to bend, or refract, light causing objects to be magnified. A plane mirror is a tool used to reflect light. A color filter is a tool that blocks certain wavelengths of light and transmits others. A prism is a tool that breaks light into the colors of the spectrum. o To use a prism appropriately, the light has to enter the prism at the correct angle to the surface in order to separate the white light. A coiled metal spring is a tool used to model waves.
High School	Use appropriately and identify the following laboratory apparatuses and materials: Balances (electronic) pH indicator paper pH buffer solution

	Beakers (50mL, 100 mL, 250mL) Chemicals & other consumable materials depending on planned laboratory investigations Prepared slides of normal cells, human cheek cells, onion root cells, bacteria, protists, fungi, sickle cell blood, whitefish blastula, etc. Erlenmeyer flasks Pipettes / droppers Evaporating dishes Petri dishes Ring stand, ring clamp, and test tube clamp , spatulas, scissors, Funnels Stoppers – rubber, cork Graduated cylinders (10 mL & 100 mL) Hand lenses (magnifiers) Test tubes, clamp, holder, and rack Test tube brushes Measuring tools (metric rulers, meter stick, meter tapes, stop watch or timer) Microscopes (compound & dissecting) Microscope slides & cover slips, light source, lens paper Lab aprons, safety goggles, gloves Tongs (crucible, beaker) Watch glasses, spot plate Wire gauze with ceramic centers Centrifuge Water bath Gel electrophoresis supplies (tray, chamber, & power supply Dialysis tubing, Parafilm, chromatography paper Mortar and Pestle Balances electronic Pipettes / droppers pH paper / pH meters Burners (Bunsen), flint strikers Chemical scoop (scapula) Stirring rods Conductivity apparatus (light bulb) Stoppers – rubber, cork Erlenmeyer flasks Test tubes, holder, and rack Evaporating dishes Test tube brushes Filter paper Thermometers (alcohol, digital) Forceps Tongs (crucible, beaker) Funnels Watch glasses

	Graduated cylinders Wire gauze with ceramic centers Hot plates Wood splints Litmus paper Ammeters and voltmeters (or multimeters) Motion carts (or toy cars) Compasses Motors, simple electric Diffraction grating Protractors Dry cells (or other voltage source) Resistors Electroscopes Coiled or large metal springs Flashlights Spectroscope Generators (hand-held) Spring scales Hand lenses (magnifiers) Switches (knife) Lenses (convex and concave) Timers Light bulb and holders Tuning forks Magnets Weights Mirrors, plane rectangular Wire, insulated copper Use the identified laboratory apparatuses in an investigation safely and accurately with o Associated technology, such as computers, calculators and other devices, for data collection, graphing, and analyzing data; and o Appropriate techniques that are useful for understanding biological concepts, such as Using a microscope appropriately o Associated technology, such as probeware and meters to gather data; and o Appropriate techniques that are useful for understanding chemistry and physics concepts, such as measuring, heating, filtering, timing, setting up circuits, electrostatics, or wave behavior.

Planning an investigation

1. Develop a testable question.
2. Predict possible outcomes.
3. Identify appropriate tools, instruments, materials, and procedures.
4. Identify possible variables that affect what you are questioning and narrow it down to the ONE you want to test. This will help you refine your question.
5. Identify controls that you will keep constant during the investigation. These will come from the list of possible variables that you choose NOT to test.

Carrying out an investigation

1. Make qualitative and quantitative observations.
2. Take measurements.
3. Structuring and organizing data (data table/chart).

Importance of Safety

It is vitally important that students use necessary and appropriate safety procedures when conducting any scientific investigation.
Suggested safety procedures (including but not limited to):

- All students and parents must sign a science course safety contract. A lab safety contract is recommended to notify parents/guardians that classroom science investigations will be hands-on and proper safety procedures will be expected. These contracts should be signed by the student and the parents or guardians and kept on file to protect the student, teacher, school, and school district. In the event of a serious laboratory safety violation or accident, follow your school or district policy for documentation.
- Conduct pre-lab safety overview. Students should be able to describe and practice all of the safety procedures associated with the activities they conduct.
- Review ALL safety considerations and possible risks prior to starting an investigation
- Use all appropriate personal safety equipment (goggles, aprons, gloves, shields, etc…) and take all appropriate safety precautions (close-toed shoes, long pants, long hair tied back, etc…)
- Follow all safety guidelines for equipment and materials/chemicals
- Monitor environment for possible disruptions, hazards, and safety violations. Address any problems immediately and appropriately
- Discontinue lab if the environment becomes unsafe/overly disruptive
- NEVER assign potentially hazardous tasks as homework
- Lab safety rules may be posted in the classroom and/or laboratory where students can view them.
- Materials Safety Data Sheets (MSDS) should be reviewed, if necessary. Special Biological Precautions: Use only nonpathogenic varieties of bacteria. Seal all petri dishes with tape. Kill all cultures before disposing of them. Wear gloves when working with bacteria and other specimens. Consult your district policy before allowing students to collect any human specimen (i.e. cheek cells or blood).

The role of prior knowledge

Prior knowledge plays an important role in how students formulate questions and generate hypotheses. In some cases, students will have prior knowledge about a particular scientific concept. Otherwise, the acquisition of prior knowledge will need to be built into the learning experience for students to have the framework to plan and carry out investigations. Some investigations may require little prior knowledge to design and conduct while others may require a great deal of background information.

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Plan scientific investigations following the appropriate grade-level criteria defined by the performance indicator. Scientific investigations answer scientifically testable questions using reproducible results from robust data sets.
- Generate testable scientific questions.
- Predict possible outcomes to an investigation or experiment.
- Generate testable hypotheses that not only predict possible outcomes, but also propose an explanation for the possible outcome (beginning at 5th grade).
- Identify materials and procedures needed to carry out an investigation.
- Identify the variables that are part of an investigations (beginning at 3rd grade).
- Use appropriate lab equipment, technology, and techniques to collect both qualitative and quantitative data.
- Record and represent data in the appropriate form.
- Use appropriate lab safety procedures.

CONNECTIONS WITH OTHER SCIENCE AND ENGINEERING PRACTICES

- Ask Questions (S.1A.1)
    - Investigations serve as the mechanisms by which evidence is acquired in an effort to construct answers to questions as well as test proposed solutions to problems.
- Analyze and Interpret Data (S.1A.4) and Use Mathematics and Computational Thinking (S.1A.5)
    - Evidence acquired through investigations and tests is analyzed and interpreted through the application of mathematics and computational thinking in order to look for patterns, trends, relationships, anomalies, etc...
- Engage in Argument from Evidence (S.1A.7) and Construct Explanations (S.1A.6)
    - Investigations provide the evidence that is used to support claims in the argumentation processes as well as to construct explanations of processes and phenomena in science. Tests of proposed design solutions provide evidence needed to identify and refine viable solutions to problems.
- Develop and Use Models (S.1A.2) and Obtain, Evaluate, and Communicate Information (S.1A.8)
    - Information and models can provide information to help students plan scientifically accurate investigations by providing important content prior knowledge. Investigations can also provide evidence needed to develop models.

- Construct Devices or Design Solutions (S.1B.1)
    - Whereas scientists plan and carry out investigations, engineers conduct tests on proposed designs for possible solutions in order to gather the data needed to analyze the efficacy of the design or solution.

PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples is to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non-Example
K	Life Science	Students predict the needs of plants and then conduct structured investigations to determine which environmental factors are necessary for plants to live and grow. Students make non-standard measurements and qualitative observations. Observations and data are recorded in a graphic organizer, journal, and/or class chart.	Teacher describes and demonstrates what plants need to live and grow. Class conducts a group investigation to verify this information.
1-2	Earth Science	After generating questions about shadows, students conduct an investigation as to how shadows change as the position of a light source changes. Students make both qualitative and quantitative measures of the change in position. Data is organized.	Students make non-standard qualitative observations about shadows without taking quantitative measurements.
3-4	Physical Science	Based on prior knowledge and student generated questions, students use provided materials to plan and conduct investigations that test how different variables affect the properties of sound (including pitch and volume). Both qualitative and quantitative data are recorded and organized in an appropriate format. Quantitative measures are made using smart technology.	Based on teacher-provided questions, students conduct a scripted investigation about the variables that affect pitch and volume to confirm anticipated outcomes.
5	Physical Science	Students are provided with materials and plan and conduct a controlled scientific investigation to test the effects of balanced and unbalanced forces on motion. Students identify experimental and control variables and record and organize qualitative and quantitative data.	Students conduct a scripted investigation to verify the variables that affect motion.
7	Chemistry	Students use sodium bicarbonate tablets, film canisters, and water to conduct a controlled	Students conduct a scripted investigation to confirm an

		investigation testing different variables to answer questions concerning physical and chemical properties.	expected chemical or physical property.
High School	Earth Science	Based on credible scientific information, students formulate scientific questions and develop a testable hypothesis on the different variables that affect the rate of weathering. Students plan and conduct a scientific investigation to test those variables, using appropriate materials, equipment, and technologies to accumulate and communicate qualitative and quantitative data.	Students conduct a series of scripted experiments to prove the expected outcomes on the variables that affect the rate of weathering.

SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1A.4: ANALYZE AND INTERPRET DATA

GRADE LEVEL PROGRESSIONS

K.S.1A.4 **1.S.1A.4** **2.S.1A.4** **3.S.1A.4**	Analyze and interpret data from observations, measurements, or investigations to understand patterns and meanings.
4.S.1A.4	Analyze and interpret data from informational texts, observations, measurements, or investigations using a range of methods (such as tabulation or graphing) to (1) reveal patterns and construct meaning or (2) support explanations, claims, or designs.
5.S.1A.4	Analyze and interpret data from informational texts, observations, measurements, or investigations using a range of methods (such as tabulation or graphing) to (1) reveal patterns and construct meaning or (2) support hypotheses, explanations, claims, or designs.
6.S.1A.4 **7.S.1A.4** **8.S.1A.4**	Analyze and interpret data from informational texts, observations, measurements, or investigations using a range of methods (such as tabulation, graphing, or statistical analysis) to (1) reveal patterns and construct meaning or (2) support hypotheses, explanations, claims, or designs.
H.B.1A.4 **H.C.1A.4** **H.P.1A.4** **H.E.1A.4**	Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions.

SPECIFIC CHANGES PER GRADE

- In grades K-3 performance expectations include the analysis of data to *understand* patterns and meanings.
- Starting in grade 4, data can come from *informational texts* as well as observations, measurements, or investigations.
- Starting in grade 4, performance expectations expand to include using a *range of methods (such as tabulation or graphing)* to conduct their analysis.
- Starting in grade 4, performance expectations expand to include the analysis of data to *reveal patterns and construct meaning or support explanations, claims, or designs.*
- Starting in grade 5, performance expectations expand to include the analysis of data to also *support hypotheses*.

- Starting in grade 6, performance expectations expand to include using *grade-level appropriate statistical analysis* as a method of data analysis and interpretation.
- Starting in grade 9, performance expectations expand to include the analysis and interpretation of data to also *refute* hypotheses, explanations, claims or designs, as well as *evaluate the strength of conclusions*.

DEFINING CHARACTERISTICS

Scientists and engineers use data as evidence to support claims, construct explanations, design solutions, and develop functional models. It is through this use of concrete, reproducible data that scientists and engineers are able to make these claims that lead to ways of describing and defining how the natural universe functions and in solving technological problems and needs with reliable, tested solutions. Data is acquired through investigation and experimentation, through the testing and manipulation of variables. Once this evidence is gathered, it must be analyzed in order to understand the significance of the data.

After data has been collected, it must be analyzed in order to determine patterns and relationships and to communicate those results to others. Scientists and engineers analyze data sets (obtained both from direct investigation and from other sources), identify correlations, recognize patterns, and determine relationships. This data is represented graphically in such ways as to communicate to others the patterns and relationships that emerge from the analysis.

In other words, analyzing and interpreting data is the process of assigning meaning to a collection of information and determining conclusions, significance, and implications. Data is analyzed and communicated to support claims, construct explanations, evaluate tested solutions, and develop functional models.

In science, analysis allows us to derive meaning from the data acquired during an investigation.
In engineering, analysis allows us to determine the success of possible solutions we are testing.

Analyzing Data

- Determining the nature and relationship of the parts
- Organizing data graphically to be able to access it
- Interpreting data (applying mathematical and statistical practices) to explain its meaning.

Scientists and engineers examine data for:

- Patterns
- Significant features
- Relationships
- Trends
- Anomalies

Causation vs. Correlation

- Correlation - two variables seem related but one does not depend on the other.
- Causation - a direct cause and effect relationship occurs between the two variables.

The goals for this practice are for students to analyze data to look for patterns or determine the validity of an initial hypothesis, to recognize when data is in conflict with initial predictions, to collate, summarize, and display data using a variety of resources (tables, charts, graphs, spreadsheets, etc...), to evaluate the validity of conclusions that can be inferred from a data set, to determine if relationships demonstrated by the data are correlative or causal, and to analyze the performance of a design.

INSTRUCTIONAL GUIDANCE AND CONSIDERATIONS

Possible sources of data

- Measurements
- Written Observations
- Drawings
- Photographs
- Computational Models
- Computer Simulations
- Maps

Guiding questions for students

- What do the data we collected mean?
- How do these data help me answer my question?

Data gathering and analysis in school

- Science notebook and journals may contain drawings, measurements/numbers, words/observations
- Tables allow organization and summary of data. A data table should be planned before the investigation starts. Consider the purpose of the table, the kind and number of items to be included in the table, the number of times a measurement will be made, and the units to be used. Data tables are often organized in columns and rows. The columns should have headings that show the quantity and unit of the data in that column. The independent (manipulated) variable is listed in the column on the left side. The dependent (responding) variable is listed in the column(s) on the right side. If qualitative data is to be gathered, include enough space to write the observations
- Graphs can be used to visually summarize and make data accessible. Graphs are visuals used to compare data. Graphs show not only information but also relationships between the data. Different types of graphs show different types of information.
- Apply mathematics to determine and express relationships between variables
- Apply statistics to define the relationship between variables (finding the slope, correlation to a line, etc.)

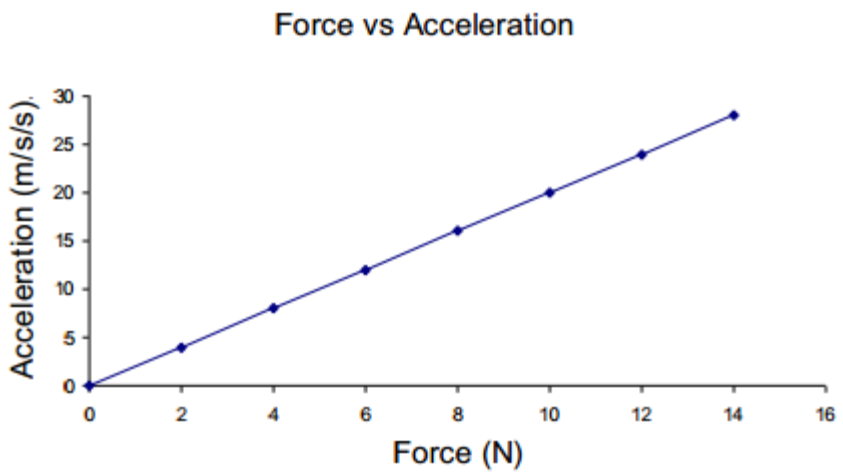
Defining Variables
Variables are factors that can affect the results of an experiment. Before an investigation begins, the variables that could affect the results must be identified. It should then be determined which one variable to change or test and which conditions should be kept the same in the experiment. Students need to know the difference between independent and dependent variables

- Independent (Manipulated) Variable - The variable that is being tested as the possible cause of the outcome that is being measured.
- Dependent (Responding) Variable - The variable that is being measured as the results from the changes made to the independent variable (this making it *dependent* upon the other).

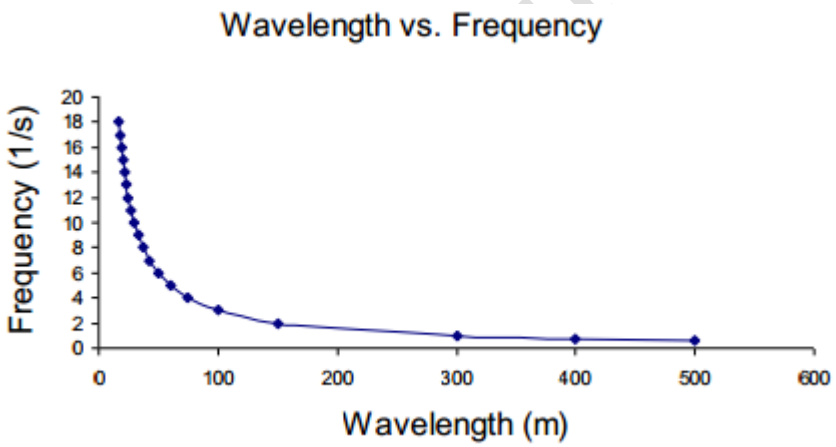
The following skills denoted as specific progressions by grade level should build upon each other as students transition from one grade level to the next grade level:

3	Students will need to identify variables
4	Students should know the characteristics of a simple scientific investigation that represent a fair test. A fair test is one in which only one factor is changed or tested in the experiment so that it can be determined whether or not that factor affected the results. Students should know that the manipulated variable is always located on the x-axis, while the responding variable is always located on the y-axis.
5	The manipulated variable (changed or tested in the experiment) is also called the independent variable. The variables that are kept the same, or unchanged, in the experiment are called the controlled variables. The responding variable (the result of, or response to, the manipulated variable) is also called the dependent variable.
6	It is essential for students to know that line graphs are used to represent data that has been collected over a determined amount of time (for example, change in fish population in a week). Once the data has been collected and organized in an appropriate data table, a graph can be constructed. To construct a line graph, the following steps should be taken: 1. Draw a horizontal line (x-axis) and a vertical line (y-axis) that meet at a right angle. 2. Identify the independent (manipulated) variable and the dependent (responding) variable from the data. o The independent (manipulated) variable is written on the x-axis. o The dependent (responding) variable is written on the y-axis. o Include appropriate units of measurement for each variable. 3. Look at the range of data (lowest and highest) to determine the intervals or increments (numbers on the axes) of the x-axis and the y-axis. o The increments do not need to be the same for both the x-axis and the y-axis, but should

	be consistent on either axis. o Label the point at the right angle as zero (0). 4. Plot the data on the graph as matched pairs. For example, every independent (manipulated) variable number will have a corresponding dependent (responding) variable number. 5. Connect the points on the line graph. 6. Write an appropriate title for the graph that contains the names of both variables. NOTE: A mnemonic device that can be used to teach the appropriate locations of the variables on a graph is DRY MIX.DRY represents Dependent-Responding-Y-axis. MIX represents Manipulated-Independent-X-axis. Bar graph – comparison; the length of the bars on a bar graph shows the quantity or amount of the qualitative factors. The members of the category are labeled on the side-to-side line at the bottom of the graph (horizontal axis); the numbers are marked on the up-and-down line (vertical axis).
High School	Recognize the implications of various graphs ○ A direct variation (or proportion) is one in which, one variable increases as the other increases or as one variable decreases the other decreases. A straight line with a positive slope indicates a direct relationship that changes at a constant rate. A greater slope indicates an increased rate of change. For example the number of bacteria growth over time. o An inverse variation (or proportion) is one in which the product of two quantities is a constant. For example the relationship between rabbits and foxes in an ecosystem. Over time, as the number of foxes increase the numbers of rabbits decrease then the number of foxes begin to decrease and the numbers of rabbits begin increase. Recognize the implications of various graphs ○ A direct variation (or proportion) is one in which, one variable increases as the other increases or as one variable decreases the other decreases. A straight line with a positive slope indicates a direct relationship that changes at a constant rate. A greater slope indicates an increased rate of change.



An inverse variation (or proportion) is one in which the product of two quantities is a constant. For example the product of the frequency and the wavelength is equal to the velocity of a wave ($v = f \lambda$). Frequency and wavelength are inversely proportional. As one quantity increases the other quantity decreases.



Use dimensional analysis to change the units of the measurement determined, not the value of the measurement itself.

o It is very important in science to express all numbers with units of measurement when appropriate, not just the number as is sometimes done in purely mathematical problems.

o To change a measurement from liters to milliliters, or grams to kilograms, for example, the measurement can be multiplied by a "conversion factor" that expresses the relationship between the given and asked- for value.

o This conversion factor is a fraction equal to one and, therefore, the value of the original measurement does not change---only the unit changes.

Note: Students should be introduced to and understand when it is appropriate to use best fit lines.

	$15\ \cancel{\text{liters}} \times \frac{1000\ \text{milliliters}}{1\ \cancel{\text{liter}}} = 15{,}000\ \text{milliliters}$ (conversion factor) $15\ \cancel{\text{milliliters}} \times \frac{1\ \text{liter}}{1000\ \cancel{\text{milliliters}}} = 0.015\ \text{liters}$

Types of graphs to use

It is essential for students to know that the data collected in simple scientific investigations should be organized in a way that represents and communicates simple data and explanations through drawings, tables, pictographs, bar graphs, and oral and written language. All drawings, tables, pictographs, and bar graphs need to be clearly labeled. Oral and written language can be used to describe observations, share data, or explain results.

- Drawings - may be pictures
- Diagrams - used to represent an observation; identify specific parts or how they work, sequence of events, how things are alike and different, or the relationship among objects or events.
- Tables - organize and represent information collected or presented. Tables are made of columns and rows. Categories are listed in the first (left) column and data collected are listed in columns to the right of the category column.
- Line graph - change over time
- Scatter plot - correlation of variables
- Bar graph – comparison; the length of the bars on a bar graph shows the quantity or amount of the qualitative factors. The members of the category are labeled on the side-to-side line at the bottom of the graph (horizontal axis); the numbers are marked on the up-and-down line (vertical axis).
- Pie graph - parts of the whole
- Pictograph - images or symbols to represent data points

Challenges associated with data collection and analysis

It is essential for students to explain why results might be different even though the same investigation testing the same factors was being done by several groups. Investigations may yield varying results based on the following factors:

- The setup of the materials was not followed properly or in the exact same way.
- Similar procedures were not followed in the exact same way.
- Tools were not used properly.
- Measurements were not taken accurately.
- Different observations were collected.
- Mistakes were made when recording data, such as numbers written incorrectly.
- Under-analyzing data - ignoring the data because of a preconceived expectation.
- Over-analyzing data - making a claim without sufficient data.
- Sources of error - not undertaking multiple trials to account for possible error.
- Selection of appropriate tools and procedures - only looking at the data one way.

Assessing the practice of analyzing and interpreting data.

- Ask students how and why they collected the data the way they did.

- Ask students to explain reasoning with the data.
- Ask students about outliers in their data.
- Ask students to explain why they analyzed it and presented it the way they did.
- Ask students if the data makes sense.
- Ask students about possible sources of error.
- Ask students about their confidence in their data and analysis.

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Use data as evidence to do the following:
  - support reasoning
  - support a claim
  - construction an explanation
  - evaluate a design or solution
- Identify trends, patterns, and relationships within a data set.
- Distinguish between causation and correlation
- Use statistical practices in analyzing data (beginning in 6th grade).
- Appropriately organize and represent data.
- Determine whether or not the data supports predicted outcomes.
- Support or refute the explanations, hypotheses, designs, or claims of others (beginning in high school)
- Evaluate strength of conclusions (beginning in high school)
- Understand that the shape of a graph can show the relationship between the variables in the hypothesis (beginning in high school)
- Understand that if the data does support the relationship, the hypothesis is still always tentative and subject to further investigation. Scientists repeat investigations and do different investigations to test the same hypothesis because the hypothesis is always tentative, and another investigation could refute the relationship predicted (beginning in high school).
- Understand that scientific theories express principles in science that have been tested and tested and always shown to support the same hypothesis. Even these theories, however, can be shown to need revision as new scientific evidence is found with improved technology, advanced scientific knowledge, and more controlled scientific investigations based on these (beginning in high school).

CONNECTIONS WITH OTHER SCIENCE AND ENGINEERING PRACTICES

- Ask Questions (S.1A.1) and Plan and Carry Out Investigations (S.1A.3)
  - The data that comes out of investigations (which themselves are derived from questions and problems) is analyzed and interpreted in an effort to look for patterns, trends, relationships, anomalies, outliers, etc...
- Use Mathematics and Computational Thinking (S.1A.5)
  - It is through the application of mathematics that data is analyzed and interpreted in order to identify trends, patterns, and relationships.

- Computational thinking involves data using computers and other technological devices to analyze, interpret, organize, and communicate data, including very large sets of "big data".

- Engage in Argument from Evidence (S.1A.7) and Construct Explanations (S.1A.6)
  - After data is analyzed and interpreted, the trends, patterns, relationships, etc… are used as evidence to support claims made using the data. They are also used in constructing viable explanations supported by the evidence/data as well as in designing and refining solutions based on the analysis of test data.
- Develop and Use Models (S.1A.2) and Obtain, Evaluate, and Communicate Information (S.1A.8)
  - Information and models provide content context and prior knowledge necessary in applying scientific principles and concepts to the analysis and interpretation of data in order to accurately determine the significance of the data as evidence (causation, relationships, etc…)
  - Data, once analyzed, can be used to develop models that describe scientific phenomena and processes.
- Construct Devices or Design Solutions (S.1B.1)
  - Engineers analyze and interpret the results of tests conducted in order to use the data as evidence in evaluating the efficacy of their designs of solutions.

PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples are to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non-Example
2	Earth Science	Based on prior knowledge of weather, students collect data on temperature, wind, and forms of precipitation from their immediate area. Data is used to describe and predict seasonal weather patterns. The students determine how to gather, record, and communicate the weather data.	Students are given weather data and an explanation of the data.
4-5	Life Science	Students grow different plants from seeds over a period of time. They record, analyze, and interpret data to reveal patterns that will be used to compare developmental stages.	Teacher will provide explanations concerning the data dealing with the stages of plant development.
8	Earth Science	The teacher provides students with sources of data (maps, information texts, USGS tables) on the location of volcanoes and earthquakes. Students	Teacher provides an interpretation of data concerning the distribution

		analyze and interpret the data in order to infer the location of plate boundaries and hot spots. Analyses should include the distribution of cluster patterns and outliers.	of earthquakes and volcanoes related to plate tectonics.
High School	Biology	Students generate a series of predictions and identify variables concerning the transmission of inherited traits in fruit flies. Students conduct an investigation to gather data about the transmission of the inherited traits. Students analyze and interpret data and perform operations on these relationships to support or refute their hypothesis. Students analyze trends and patterns in the data to support or refute their hypothesis and use (grade-appropriate) statistical analyses to evaluate the strength of their conclusion.	Teacher prescribed lab on inheritable traits to validate expected outcomes.

SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1A.5: USE MATHEMATICAL AND COMPUTATIONAL THINKING

GRADE LEVEL PROGRESSIONS

K.S.1A.5	Use mathematical thinking to (1) recognize and express quantitative observations, (2) collect and analyze data, or (3) understand patterns and relationships.
1.S.1A.5	Use mathematical and computational thinking to (1) recognize and express quantitative observations, (2) collect and analyze data, or (3) understand patterns and relationships.
2.S.1A.5 **3.S.1A.5**	Use mathematical and computational thinking to (1) express quantitative observations using appropriate English or metric units, (2) collect and analyze data, or (3) understand patterns, trends and relationships.
4.S.1A.5	Use mathematical and computational thinking to (1) express quantitative observations using appropriate English or metric units, (2) collect and analyze data, or (3) understand patterns, trends and relationships between variables.
5.S.1A.5	Use mathematical and computational thinking to (1) express quantitative observations using appropriate metric units, (2) collect and analyze data, or (3) understand patterns, trends and relationships between variables.
6.S.1A.5 **7.S.1A.5** **8.S.1A.5**	Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) collect and analyze data, (3) express relationships between variables for models and investigations, or (4) use grade-level appropriate statistics to analyze data.
H.B.1A.5 **H.C.1A.5** **H.P.1A.5** **H.E.1A.5**	Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.

SPECIFIC CHANGES PER GRADE

- In grades K-1 performance expectations include being able to recognize and express *quantitative observations*.
- Starting in grade 1, performance expectations expand to include using *computational thinking* as well as mathematics.

    - In this context, computational thinking includes the use of technology and tools to analyze, manipulate, and represent sets of data (e.g. computer spreadsheets and graphing tools).
- Starting in grade 2, performance expectations expand to include using *appropriate English or metric units*.
- Starting in grade 2, performance expectations expand to include understanding *trends* as well as patterns and relationships.
    - In this context, the distinction between a pattern and a trend is that patterns are repeated sequences of data whereas trends represent the general direction or progression of a change or development of a natural phenomenon or process.
- Starting in grade 4, performance expectations expand to include using mathematics and computational thinking to understand *relationships between variables*.
- Starting in grade 5, students should use *metric units* **only**. English units of measure are no longer appropriate to gather as data from this grade forward.
- Starting in grade 6, performance expectations expand to include using mathematics and computational thinking to *use and manipulate metric units*.
    - In this context, manipulate refers to converting metric units for use with specific equations, such as density.
- Starting in grade 6, performance expectations expand to include using mathematics and computational thinking to *express relationships between variables for models and investigations*.
- Starting in grade 6, performance expectations expand to include using *grade-level appropriate statistics* to analyze data.
- Note that although the high school science performance indicators for this practice no longer specify that students *collect and analyze data*, it is expected and inferred that students will collect and analyze data as part of this practice.

DEFINING CHARACTERISTICS

Mathematics allows for a clear, consistent means of defining, describing, and communicating about natural phenomena and engineered designs in a precise way. Computational thinking and tools allow for the development of simulations to describe and test phenomena and the design and evaluation of solutions. They both allow for simulations that are used to test a variety of theories and solutions. They are essential for the analysis and representation of data.

Mathematics
All science is ultimately based in mathematics. Mathematics produces consistency, reliability, and reproducibility in science and engineering. Mathematics allows for the numerical representation of:

- Variables
- Relationships
- Predictions
- Models

Quantitative Models
Quantitative models are mechanisms for organizing and representing data in such a way that it can be analyzed and interpreted through the application of mathematical and statistical tools.

- Data tables

- Graphs of relationships
- Statistical displays (pie graphs)
- Pictorial science models

Computational Thinking
Computational thinking is way of using computers to help us apply mathematical and statistical approaches and tools to model and understand the world. This includes:
- Simulation software
- Efficient ways to collect extensive data
- Engineering simulations

Big Data
We are immersed in a world of vast amounts of data that informs scientific discovery and design innovation. The goals for this practice are for students to recognize quantities and use appropriate scientific units, to recognize that simulations are based on mathematical models, to use mathematical models with real-world phenomena, and to use mathematical and statistical methods in analyzing data.

INSTRUCTIONAL GUIDANCE AND CONSIDERATIONS

Goals for using math in the classroom
- Using quantities and units
- Mathematical relationships in data

Goals for using computational thinking in the classroom.
- Organizing, manipulating, and representing large amounts of data
- Building mathematical models
- Running simulations

Quantitative reasoning progression
- Quantitative action - applying mathematical attributes/measurements to objects and relationships
- Quantitative literacy - describing objects, relationships, and processes mathematically
- Quantitative interpretation - using models to identify trends and patterns, and make predictions
- Quantitative modeling - creating and revising mathematical representations to explain phenomena

Ways students use math and computational thinking in science
- Using basic mathematics to make calculations and measurements
- Interpreting graphs and models
- Making predictions
- Creating scientific mathematical models
- Using computer simulations and models to analyze extensive amounts of data (big data).

Suggested prompts for the application of mathematics to scientific models or graphs.

Questions	Tasks
• What are the variables in this model? • What does the model illustrate? • What conclusions can you make from the model? • How do certain factors influence one or more variables? • What is the mathematical relationship between variables? • What measurements are associated with the model? • What trends and patterns are evident in the data/model?	• Identify and describe (quantitatively) the parts and processes in the model • Make predictions based off the model

Creating simple mathematical models

- Describe and study observable phenomena.
- Quantify their observations with measurements.
- Illustrate the data graphically.
- Write a mathematical formula to describe the trend in the model.
- Make quantitative predictions using the model.

Progression

These tasks are represented by increasing levels of complexity in order to scaffold classroom engagements as appropriate to the skills of the students. This is not intended to imply that less complex tasks are not appropriate for students capable of more complex mathematical practices.

- Using quantities and units as sources of data
- Making measurement using tools
- Organizing data into charts and graphs
- Using spreadsheets to organize and make calculations
- Using words and symbols to represent mathematical relationships
- Using probes to gather large amounts of data
- Running simulations as sources of data

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Recognize and communicate quantitative data using appropriate methods and units (Kindergarten only uses non-standard units).
- Use computational thinking and resources to organize, manipulate, and represent large sets of data (beginning in 1st grade).
- Determine and distinguish relationships, patterns, and trends in data and models.
- Use grade-level appropriate statistics to analyze data (beginning in 6th grade). Grade level appropriateness of statistics is determined by the specific grade level math standards.

CONNECTIONS WITH OTHER SCIENCE AND ENGINEERING PRACTICES

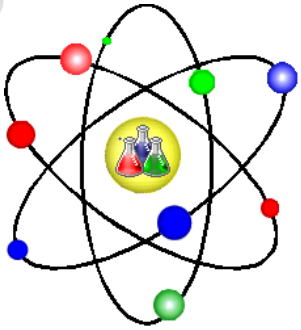
- Ask Questions (S.1A.1) and Plan and Carry Out Investigations (S.1A.3)
  - The data that comes out of investigations (which themselves are derived from questions and problems) is analyzed and interpreted in an effort to look for patterns, trends, relationships, anomalies, outliers, etc...
- Analyze and Interpret Data (S.1A.4)
  - It is through the application of mathematics that data is analyzed and interpreted in order to identify trends, patterns, and relationships.
  - Computational thinking involves data using computers and other technological devices to analyze, interpret, organize, and communicate data, including very large sets of "big data".
- Engage in Argument from Evidence (S.1A.7) and Construct Explanations (S.1A.6)
  - After data is analyzed and interpreted, the trends, patterns, relationships, etc… are used as evidence to support claims made using the data. They are also used in constructing viable explanations supported by the evidence/data as well as in designing and refining solutions based on the analysis of test data.
- Develop and Use Models (S.1A.2) and Obtain, Evaluate, and Communicate Information (S.1A.8)
  - Information and models provide content context and prior knowledge necessary in applying scientific principles and concepts to the analysis and interpretation of data in order to accurately determine the significance of the data as evidence (causation, relationships, etc…)
  - Data, once analyzed, can be used to develop models that describe scientific phenomena and processes.
- Construct Devices or Design Solutions (S.1B.1)
  - Engineers apply mathematics and computational thinking in the analysis and interpretations of the results of tests conducted in order to use the data as evidence in evaluating the efficacy of their designs of solutions.

PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples are to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non-Example
1	Life Science	Students grow plants and make measurements throughout the process. Students enter data about the growth over time into a spreadsheet and generate	Students observe the stages of plant growth without utilizing

		graphs and representations of that growth	computational tools.
2	Life Science	Students conduct observations of pill bugs in order to describe how they react to changes in their environment. Students enter data in a spreadsheet to generate graphs to understand and communicate patterns, trends, and relationships among changes in the environment and behavior.	Students observe pill bugs and teacher provides explanation of behaviors.
5	Physical Science	Students collect data on distance and time as cars move down ramps. Students calculate velocities and enter data spreadsheets to create graphs to predict how changes in variables will affect motion.	Students collect data on distance and time as cars move down ramps. Students calculate velocities.
7	Physical Science	Using experimentally acquired data, students calculate density from mass and volume, enter data in spreadsheets, and generate graphs. Graphs are used to describe the relationship among mass, volume, and density. Students convert units. Students match calculated densities to actual densities to calculate percent error. Students use the graph to predict densities as either mass or volume change.	Students calculate the density of various objects.
High School	Chemistry	Using experimentally acquired data, students calculate and express relationships among variables for investigations where they predict the quantities of reactants required and the products produced in a given chemical reaction.	Balancing teacher-generated equations



SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1A.6: CONSTRUCT EXPLANATIONS

GRADE LEVEL PROGRESSIONS

K.S.1A.6	Construct explanations of phenomena using (1) student-generated observations and measurements, (2) results of investigations, or (3) data communicated in graphs, tables, or diagrams.
1.S.1A.6 **2.S.1A.6**	Construct explanations of phenomena using (1) student-generated observations and measurements, (2) results of scientific investigations, or (3) data communicated in graphs, tables, or diagrams.
3.S.1A.6 **4.S.1A.6** **5.S.1A.6**	Construct explanations of phenomena using (1) scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
6.S.1A.6 **7.S.1A.6** **8.S.1A.6** **H.B.1A.6** **H.C.1A.6** **H.P.1A.6** **H.E.1A.6**	Construct explanations of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.

SPECIFIC CHANGES PER GRADE

- Starting in grade 1, performance expectations expand to include using the results of *scientific investigations*, as defined in S.1A.3, Plan and Carry Out Investigations
- Starting in grade 3, performance expectations expand to include using the following as evidence to construct explanations: *scientific evidence and models*, *conclusions from scientific investigations*, *predictions based on observations and measurements*.
- Starting in grade 6, performance expectations expand to include using both *primary and secondary scientific evidence*.
    - In this context, primary scientific evidence refers to evidence directly gathered through student investigations and observation whereas secondary scientific evidence refers to evidence that has been acquired by other sources (e.g. national weather data from NOAA).

Scientists construct explanations in order to describe phenomena, predict future events, or make inferences about past events. Far from guesses, scientific theories and explanations are constructed from bodies of knowledge and evidence, are refined when new evidence becomes available, and must withstand scientific scrutiny. By contrast, a scientific hypothesis is neither a scientific theory, nor a guess. It is a plausible explanation for something that serves as the basis for a testable prediction. Scientific explanations link scientific theory with specific observations or phenomena that serve as evidence to support these explanations. Similarly, engineers design solutions to problems and needs through the process of identifying a need, developing a plan, testing a solution, evaluating the solution, and refining/redesigning based on performance and data.

Constructing Explanations
In science, explanations are constructing through the following process:

- A question is posed.
- Different ideas are proposed as hypotheses (plausible explanations) to answer the question.
- These ideas are tested experimentally.
- Evidence from the experiments is evaluated to determine whether or not it supports the idea.
- If the evidence does not support the idea, the scientist must start again with a different idea.
- If the evidence does support the idea, it can then lead to a theory that can be used to explain some natural phenomena.

It is important to note the difference between a theory (constructed explanation supported by evidence) and a hypothesis.

A hypothesis

- is NOT a theory.
- is NOT just an educated guess.
- IS a plausible explanation for some phenomena.

Design Process
Similarly, the design process follows a sequence to meet a need or construct a solution.

- Identify a problem to be solved or a need to be fulfilled.
- Design a solution that addresses this need or problem.
- Create and test the solution.
- Evaluate the solution.
- Based on the evaluation of data acquired when the solution is being tested, the initial design may be further refined and improved.

In both processes (constructing explanations and designing solutions), data and observations are used as evidence to evaluate the validity of a plausible explanation or proposed design and can lead to the refinement of either.

The goals for this practice are for students to construct their own explanations based on their knowledge and linked to models and evidence, to use scientific evidence to support, refine, or refute explanations, to identify gaps in proposed explanations, to solve design problems through

undertaking the design process, to construct or test a design solution, and to evaluate and critique competing solutions.

INSTRUCTIONAL GUIDANCE AND CONSIDERATIONS

Student challenges in using evidence

- Use evidence to support their ideas.
  - Students want to rely on their own opinions and have difficulty using sufficient evidence.
- Explain why their evidence supports their ideas.
  - Student have difficulty articulating the link between their ideas and supporting evidence.
- Consider multiple explanations.
  - Students tend to focus on only one idea.
- Revising explanations and solutions based on new evidence or scientific knowledge.
  - Students have a hard time abandoning their original ideas.

Developing compelling questions/problems

For students to construct explanations or design solutions, they must start with a compelling question or problem. To develop a compelling question/problem you must:

- Identify the data students can use as evidence
- Identify scientific principles (core ideas) students can apply to make sense of the data
- Ensure that there are multiple plausible answers
- Consider the clarity of the question

What to look for in explanations and solutions

- The claim (the proposed explanation or solution)
- Supporting evidence, including evidence of reproducibility and of repeated trials
- Reasoning behind how the evidence supports the claim

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Use evidence from appropriate sources to describe the cause and effect relationship or a process or phenomenon. Appropriate sources of evidence are defined by each grade-level performance indicator.
- Support their reasoning using appropriate evidence.
- Connect their supporting evidence to a claim or proposed explanation.

CONNECTIONS WITH OTHER SCIENCE AND ENGINEERING PRACTICES

- Ask Questions (S.1A.1) and Plan and Carry Out Investigations (S.1A.3)
  - The data that comes out of investigations (which are driven by questions and problems) is used as evidence to construct explanations which serve as answers to questions. When tests of proposed solutions are conducted, the data from those tests is used to refine and design viable solutions to problems.

- Analyze and Interpret Data (S.1A.4) and Use Mathematics and Computational Thinking (S.1A.5)
    - When analyzed through the application of mathematics, data becomes evidence that is ultimately used to construct and support explanations as well as refine the design of viable solutions to problems.
- Engage in Argument from Evidence (S.1A.7)
    - The argumentation process uses evidence to support claims made about the causation of phenomena or the best design solution. Those claims that are successfully supported by the evidence and stand up to scientific scrutiny can become explanations and solutions.
- Obtain, Evaluate and Communicate Information (S.1A.8) and Developing and Using Models (S.1A.2)
    - Part of the process of constructing explanations can involve accessing and applying prior knowledge and information. Models can also serve as a source of prior knowledge in the construction of valid explanations.
    - Explanations can also lead to the development of models that can be used to communicate processes and phenomena defined by these explanations.
- Construct Devices or Design Solutions (S.1B.1)
    - Just as scientists construction explanations supported by evidence, engineers design solutions that have been tested and supported by data that has been analyzed and evaluated.

PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples are to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non-example
K	Life Science	After observing worms, snails, and chicks, students use data collected from their observations to support claims about what animals need to survive including air, water, nutrients, and shelter.	Students watch a video about different animals and what they need to survive. Students write or draw what animals need based on the video.
1-2	Life Science	After observing plant growth over a structured period of time and under a variety of student-generated conditions, students will collect data on plant growth. Their data will be organized in a graph, table, or diagram to depict the data they collected. Students will use the data to construct explanations of what occurs during each stage of	Students will watch plants that the teacher has planted grow and chart their growth on a teacher made sheet.

		plant growth.	
4	Earth Science	Students use online data or other informational text to study and compare the long term weather conditions of several regions. Students reason with their data to construct an explanation for the climate differences between regions.	Students are provided data and teacher explains the meaning of the data and provides chart outlining climate differences between regions.
5	Earth Science	After explorations with a virtual and physical watershed model (stream tables), students use data collected through observations to make inferences about how various landform features have formed. Students work in groups to reach consensus.	Students watch a video and take notes on how landforms are shaped by the movement of water on Earth.
7	Life Science	Students conduct research on different diseases, focusing on the effect the disease has on specific organ systems. Students use information from their research to support an explanation for how the loss of function of an affected organ system harms the entire human body as a result of the interdependent nature of the major human body systems.	Students do research on different organ systems and present their findings to the class.
High School	Earth Science	Students analyze seismic evidence from around the world and plot seismic activity data on a world map. Reasoning with the map and seismic data, students support an explanation of the relationship between the forces responsible for crustal movement and the occurrence of landforms and seismic/tectonic activity.	Students take notes on the relationship between tectonic forces, activity, and landforms. They then plot the occurrence of the activity on a map to validate the expected outcomes from their notes.

SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1A.7: ENGAGE IN SCIENCTIFIC ARGUMENTS FROM EVIDENCE

GRADE LEVEL PROGRESSIONS

K.S.1A.7	Construct scientific arguments to support explanations using evidence from observations or data collected.
1.S.1A.7 **2.S.1A.7**	Construct scientific arguments to support claims or explanations using evidence from observations or data collected.
3.S.1A.7 **4.S.1A.7** **5.S.1A.7**	Construct scientific arguments to support claims, explanations, or designs using evidence from observations, data, or informational texts.
6.S.1A.7 **7.S.1A.7** **8.S.1A.7**	Construct and analyze scientific arguments to support claims, explanations, or designs using evidence from observations, data, or informational texts.
H.B.1A.7 **H.C.1A.7** **H.P.1A.7** **H.E.1A.7**	Construct and analyze scientific arguments to support claims, explanations, or designs using evidence and valid reasoning from observations, data, or informational texts.

SPECIFIC CHANGES PER GRADE

- In Kindergarten, performance expectations include *supporting explanations using evidence* from observation or collected data.
- Starting in grade 1, performance expectations expand to include *supporting claims* as well as explanations.
- Starting in grade 3, performance expectations expand to include *supporting designs*.
- Starting in grade 3, performance expectations expand to include the use of *information texts* as evidence.
- Starting in grade 6, performance expectations expand to include the *analysis of scientific arguments*.
- Starting in grade 9, performance expectations expand to include using evidence and *valid reasoning*.

Scientists and engineers engage in reasoning and argumentation from evidence to propose new explanations and theories, to interpret data, and to propose and evaluate technological design solutions. Arguing from evidence is an essential part of the scientific process in order to identify weaknesses and limitations in explanations and design. It is essential that scientists, engineers, and citizens possess the capacity to evaluate claims and judgments about the validity of science-related topics and events, as well as to detect "bad science". Engineers use argument as part of the process of evaluating the initial stages of a design in order to compare competing proposed solutions to a problem or need.

In science, engaging in argument leads towards identifying the best explanation for a phenomenon. In engineering, argument leads towards the development of the best possible solution to a problem.

Scientists and engineers understand that engaging in argument is not about personal ego. Arguing in science and engineering is not about fighting over who is right and who is wrong. It is about coming to the best explanation or solution *supported by evidence*. Scientists and engineers do not feel threatened if their claim or solution is challenged, shown to be inaccurate, or is demonstrated to not be the best solution to the problem.

Two types of arguments

- Informal: Putting forth ideas and sharing them with others in a dialogue where these ideas are discussed and debated in an informal manner.
- Formal: Conducting investigations to gather evidence in support of an explanation, the results of which are then put forth for formal peer review where other scientists attempt to replicate the results of the investigation to either support or refute the proposed explanation.

The goals of argument in science and engineering are to:

- construct arguments as proposed explanations to questions or proposed solutions to problems.
- defend claims and models using evidence and reasoning
- critique other claims and arguments using evidence.
- engage in peer review to see if proposed/published results can be replicated.

Additionally, scientists and engineers use argument to defend:

- interpretation of data
- experimental designs
- method of data analysis
- appropriateness of a question

Difference between argument and explanation

- Explanations are the products of science, how and why phenomena occur, supported by evidence.
- Argumentations is the process of defending explanations by carefully ruling out alternative explanations and building a case using evidence for the current claim.

Argumentation is the process of building explanations. Explanations are the final products of the process.

Benefits of argumentation in science

- Supports students' understandings of scientific concepts
- Argumentation from evidence is an important 21st century life skill
- Promotes literacy development (strong English Language Arts connection)
- Helps students building an understanding of the nature of science and the development of scientific concepts and ideas
- Allows students to critically examine claims made by others and the media

The goals for this practice are for students to construct scientific arguments supported by data; to identify weaknesses in scientific arguments (of others and their own) using reasoning and evidence; to recognize that scientific arguments include claims, data, and reasoning; to explain the nature of scientific controversies and indicate why one particular theory succeeded; and to read media reports of science or technology in a critical, evaluative manner.

INSTRUCTIONAL GUIDANCE AND CONSIDERATIONS

Student challenges in using evidence.

- Use evidence to support their ideas
  - Students want to rely on their own opinions and have difficulty using sufficient evidence
- Explain why their evidence supports their ideas
  - Student have difficulty articulating the link between their ideas and supporting evidence
- Consider multiple explanations and the viewpoints of others
  - Students tend to focus on only one idea
- Revising explanations and solutions based on new evidence or scientific knowledge
  - Students have a hard time abandoning their original ideas

Instructional strategies for employing argumentation

- Provide a framework and communicate expectations
- Model and describe performance expectations
- Provide examples
- Communicate the importance of the process
- Critique each other's written arguments
- Allow students to debate ideas
- Provide various scaffolds to facilitate (e.g. guiding questions)

A framework for argumentation

1. Make a claim (a conclusion about a problem).
2. Provide appropriate scientific data to sufficiently support the claim.
3. Provide reasoning for why the data counts as evidence in the context of appropriate scientific principles to support the claim.
4. Describe other plausible claims.
5. Provide counter evidence and reasoning to rebut alternate claims.

A framework for debate

- Give students permission to disagree.
- Establish norms of acceptable behavior.
    - Students should use evidence and reasoning to support their claims.
    - Students should NOT put down other students' ideas.
    - Students should NOT talk when someone else is talking to the class.
- Help students learn to listen.

It is important that students understand that engaging in argument in science and engineering is not about personal ego. Arguing in science is not about fighting over who is right and who is wrong. It is about coming to the best explanation or solution *supported by evidence*. Students should not feel threatened if their argument/explanation is challenged or proven inaccurate. Teachers should model this practice.

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Use evidence to support claims made about natural phenomena. Evidence can come from student generated observations, measurements, models, scientific text and media, secondary sources of data.
- Analyze and evaluate other claims based on scientific evidence.
- Determine if the evidence supports a scientific claim.
- Use evidence to support claims made about designs and solutions.

CONNECTIONS WITH OTHER SCIENCE AND ENGINEERING PRACTICES

- Ask Questions (S.1A.1) and Plan and Carry Out Investigations (S.1A.3)
    - Questions and problems lead to Investigations and tests which generate evidence that is used to support claims through argumentation.
- Analyze and Interpret Data (S.1A.4) and Use Mathematics and Computational Thinking (S.1A.5)
    - In order for data to serve as evidence in supporting claims, it must be analyzed and interpreted in order to identify patterns and trends, determine relationships and causation, and identify anomalies.
- Construct Explanations (S.1A.6)
    - Claims that are successfully supported and survive the argumentation process can lead to viable scientific explanations or successful designs.
- Obtain, Evaluate, and Communicate Information (S.1A.8) and Develop and Use Models (S.1A.2)
    - Information and models can provide context and prior knowledge used in framing claims using evidence.
    - Claims successfully defended through argumentation and supported by evidence lead to scientific explanations that, in turn, can lead to the development of models to communicate phenomena and processes.
- Construct Devices or Design Solutions (S.1B.1)

- Whereas scientists support claims using reasoning and evidence, engineers use reasoning and evidence support proposed designs and solutions that have been tested.

PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples are to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non-Example
2	Physical Science	Students conduct a series of investigations in which they conduct observations of matter as heat is added and removed, resulting in changes from solid to liquid and liquid to solid (freezing and melting). Students use data from their observations to support claims that some changes in matter are reversible when heat is added or removed and some are not.	Students make observations of melting and freezing and list their observations in a chart.
3	Earth Science	Students gather observational data from a variety of fossils. Students make inferences, supported by their data, for what type of environments the organisms must have lived in when they were alive in the past. Students find the locations of their fossils on a map and construct scientific arguments supported by their data for what the environment at each location was once like.	Students watch videos or read books about fossils and take notes on what kinds of plants and animals used to live in the past.
5	Earth Science	Students use data from the US Forest service to analyze the impact of human activity on woodlands. Students reason through their analysis to support claims for how human activities, both beneficial and detrimental, have impacted the affected area.	Students watch a video about the effect of human activities on the land and write a summary.
7	Life Science	Students obtain information through library and online research and explorations about the various roles bacteria play in organisms and the environment. Students reason with this information to support the claim that bacteria can be both harmful and helpful.	Students fill in a T chart or other graphic organizer to list the pros and cons of bacteria.

High School	Biology	Students read different scientific journal articles about pros and cons of the biotechnological applications of stem cells and evaluate the claims made in the articles. They then use information from the articles and additional research to support or challenge the claims made in the articles based on the validity of the data and procedures.	Students generate a chart comparing the pros and cons of stem cell research and medical applications.

SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1A.8: OBTAIN, EVALUATE, AND COMMUNICATE INFORMATION

GRADE LEVEL PROGRESSIONS

K.S.1A.8 **1.S.1A.8** **2.S.1A.8**	Obtain and evaluate informational texts, observations, data collected, or discussions to (1) generate and answer questions about the natural world, (2) understand phenomena, (3) develop models, or (4) support explanations. Communicate observations and explanations using oral and written language.
3.S.1A.8 **4.S.1A.8**	Obtain and evaluate informational texts, observations, data collected, or discussions to (1) generate and answer questions, (2) understand phenomena, (3) develop models, or (4) support explanations, claims, or designs. Communicate observations and explanations using the conventions and expectations of oral and written language.
5.S.1A.8	Obtain and evaluate informational texts, observations, data collected, or discussions to (1) generate and answer questions, (2) understand phenomena, (3) develop models, or (4) support hypotheses, explanations, claims, or designs. Communicate observations and explanations using the conventions and expectations of oral and written language.
6.S.1A.8 **7.S.1A.8** **8.S.1A.8** **H.B.1A.8** **H.C.1A.8** **H.P.1A.8** **H.E.1A.8**	Obtain and evaluate scientific information to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.

SPECIFIC CHANGES PER GRADE

- Starting in grade 3, performance expectations expand to include supporting *claims and designs* as well as explanations.
- Starting in grade 3, performance expectations expand to include the *use of the conventions and expectations of language*.
- Starting in grade 5, performance expectations expand to include supporting *hypotheses*.
- Starting in grade 6, performance expectations expand significantly to include the use of *scientific information* to engage in the following: *answer questions, explain or describe phenomena, evaluate hypotheses, explanations, claims or designs, identify and/or fill gaps in knowledge*.

- Starting in grade 6, performance expectations expand to include *evaluating grade-appropriate primary or secondary scientific literature* or *reporting the results of student experimental investigations*.
    - In this context, primary scientific literature refers to papers and articles from science journals and science media (e.g. the journal *Nature*) whereas secondary scientific literature refers to papers and articles that summarize research, data, and explanations first published in primary literature and media (e.g. *NPR.org*)

DEFINING CHARACTERISTICS

Science and engineering are ways of knowing that are represented and communicated by words, diagrams, charts, graphs, images, symbols, models, and mathematics. As part of the scientific and engineering processes, one must have the capacity to obtain the relevant information necessary to support claims and explanations, make predictions and inferences, and evaluate designs and solutions. Scientists and engineers evaluate information to make sure it is accurate. And they communicate information in a variety of ways so that others can understand and benefit from what has been learned and designed.

This practice includes:

- Reading, interpreting, and producing "texts"
- Spoken communication
- Critically evaluating science and engineering "products"
- Obtaining science and engineering information

Types of multimodal texts

- Traditional texts-- textbooks, primary (technical) literature, popular science articles
- Graphs
- Diagrams
- Tables
- Equations
- Symbols
- Adapted Primary Literature- a narrative is derived from technical literature to make it more accessible.

Communicating

- Presentations (both spoken and poster)
- Formal and informal modes of communication
- Discussions
- Teaching
- Digital publishing
- Digital media (videos, websites, blogs, social media networks, etc…)

The goals for this practice are for students to use words, diagrams, tables, and graphs to communicate their understandings or ask questions, to read and explain key ideas from scientific and technical sources of information, and to engage in critical reading of primary scientific literature or media reports of science and discuss the validity and reliability of what is being presented.

Goals for the classroom.

- Consume information
  - textbooks
  - primary literature
- Create information
  - Communicate understandings
  - Share information (writing and presentation)

Challenges for students.

- Unfamiliarity with scientific jargon, academic vocabulary, and technical sentence structures
- Lack of foundation in this area
- Lack of a logical flow of information in expository texts
- Generate narrative when interpreting text as opposed to extracting information
- Accessing information through multimodal means (diverse media communicating information)

What we want our students to do

- Reading primary literature (not just textbooks or science "stories")
- Producing multimodal science and engineering communications
- Science note books (drawings, numbers, words, inferences, predictions, experiences)
- Publishing formal reports (presentations, written reports, mini-posters, digital publishing, e-portfolios)
- Evaluate the validity and reliability of sources, claims, and data

In order to facilitate this, science and engineering teachers will need to provide explicit instruction and reading strategies for accessing a variety of primary and secondary sources of information. It will also be necessary to provide explicit instructions on reading tables, graphs, graphics, etc… Teachers cannot assume that they won't have to teach reading.

Some specific examples--

- High School
  - Writing a research design plan
  - Presenting results and making claims
  - Writing abstracts
  - Analyzing and annotating research
- Middle School
  - Scientific debates
  - Evaluating and arguing claims using evidence from research
- Elementary School
  - Creating PSAs supported by evidence from research
  - Research days to address student interest questions about the natural world
  - Sharing information with peers through drawings, conversations, etc...

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Obtain scientific information necessary to perform specific tasks (defined by specific grade-level the performance indicators) from a variety of sources. Scientific information includes information from scientific text and media, primary and secondary data and observations, models, discussions.
- Evaluate scientific information to determine its scientific accuracy.
- Generate and answer scientific questions using sources of information.
- Use scientific information to support claims, generate models, support reasoning, explanations, claims, and designs.
- Communicate scientific information in an appropriate manner (orally, written, visually, mathematically).

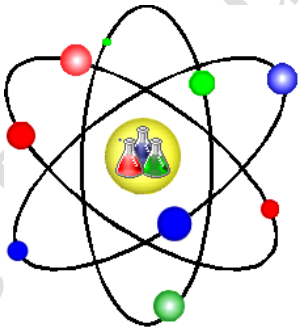
CONNECTIONS WITH OTHER SCIENCE AND ENGINEERING PRACTICES

- Ask Questions (S.1A.1) and Plan and Carry Out Investigations (S.1A.3)
    - Information provides context and prior knowledge to refine the process of developing a scientific question and planning an appropriate investigation
- Analyze and Interpret Data (S.1A.4) and Use Mathematics and Computational Thinking (S.1A.5)
    - Information provides a context for interpreting data and attempting to make meaning of the evidence gathered through investigations
    - It also involves the organization and representation of data and evidence
- Engage in Argument from Evidence (S.1A.7) and Construct Explanations (S.1A.6)
    - Information provides context to frame a scientific claim and construct a viable explanation by allowing the evidence to be evaluated and understood in the context of the larger pool of information surrounding the disciplinary core ideas of the content.
    - It also involves how the claims and explanations developed from evidence are communicated out and evaluated by others.
- Develop and Use Models (S.1A.2)
    - The practice of obtaining information can include identifying and evaluating existing models to use as well as provide the content context for developing one's own models based on evidence and understanding of scientific principles.
- Construct Devices or Design Solutions (S.1B.1)
    - Engineering is the application of scientific principles and concepts through the development of successful design and solutions to meet needs and solve problems. Engineers must obtain and evaluate information as part of the process of applying scientific principles to the design process. They also obtain and evaluate information about previous attempts to design solutions for similar needs or problems.
    - Engineers must be able to successfully communicate information about their designs.

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples are to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non-Example
1	Physical Science	Students are challenged to find evidence that supports the claim that light is required to make objects visible. Students obtain information from both informational texts and investigations to construct a model that illustrates how light is necessary for humans to see things.	Students watch a video or read a book about light.
4	Life Science	Students obtain information from primary (science journal articles) and secondary (textbooks) sources about different plants. Students sketch or model the different characteristics of the plants and use these models to classify the plants as flowering or non-flowering based on their characteristics. Students communicate the results in class.	Students are shown pictures, and the teacher explains how different plants are classified.
5	Life Science	Students obtain information from primary sources (science journal articles) and secondary sources (textbooks) about the biotic factors of different terrestrial and aquatic ecosystems. Students use this information to develop models of terrestrial and aquatic ecosystems that accurately incorporate the different biotic factors, comparing the factors of one ecosystem with another.	Students read about and take notes on the biotic factors of different ecosystems.
7	Life Science	Students obtain information about the relationship between genes and chromosomes from age-appropriate primary references (science journals). Students reason with this information to construct an explanation for the role	Students take notes from textbooks and presentations about genes and chromosomes and how they are related to an organism's inherited characteristics.

		genes and chromosomes play in inherited characteristics and report their findings to their class.	
High School	Chemistry	Students obtain information about technological applications of alpha, beta, and gamma radiation from primary sources (science journals), including details about mass, charge, and penetrating power. Students reason with this information to support claims about the benefits and risks associated with nuclear power and radiation, comparing the different types of radiation.	Students conduct research from textbooks and notes about the different types of radiation and write a report about their findings.



SCIENCE AND ENGINEERING PRACTICES PERFORMANCE EXPECTATIONS PERFORMANCE INDICATOR S.1B.1: CONSTRUCT DEVICES OR DESIGN SOLUTIONS

GRADE LEVEL PROGRESSIONS

K.S.1B.1 **1.S.1B.1** **2.S.1B.1**	Construct devices or design solutions to solve specific problems or needs: (1) ask questions to identify problems or needs, (2) ask questions about the criteria and constraints of the devices or solutions, (3) generate and communicate ideas for possible devices or solutions, (4) build and test devices or solutions, (5) determine if the devices or solutions solved the problem, and (6) communicate the results.
3.S.1B.1 **4.S.1B.1** **5.S.1B.1**	Construct devices or design solutions to solve specific problems or needs: (1) ask questions to identify problems or needs, (2) ask questions about the criteria and constraints of the devices or solutions, (3) generate and communicate ideas for possible devices or solutions, (4) build and test devices or solutions, (5) determine if the devices or solutions solved the problem and refine the design if needed, and (6) communicate the results.
6.S.1B.1 **7.S.1B.1** **8.S.1B.1** **H.B.1B.1** **H.C.1B.1** **H.P.1B.1** **H.E.1B.1**	Construct devices or design solutions using scientific knowledge to solve specific problems or needs: (1) ask questions to identify problems or needs, (2) ask questions about the criteria and constraints of the device or solutions, (3) generate and communicate ideas for possible devices or solutions, (4) build and test devices or solutions, (5) determine if the devices or solutions solved the problem and refine the design if needed, and (6) communicate the results.

SPECIFIC CHANGES PER GRADE

- Starting in grade 3, performance expectations expand to include not only evaluating a device or solution but also *refining the design if needed*.
- Starting in grade 6, performance expectations expand to include the *use scientific knowledge* to solve specific problems or needs.

DEFINING CHARACTERISTICS

Where science is the process of investigating the universe through asking questions, gathering and analyzing data, constructing explanations and models to describe phenomena, and communicating what is learned, engineering is the application of scientific principles and knowledge in the search for a solution to a problem or need. Despite these differences, the practices of engineering are analogous to the practices of science.

The Engineering Process

The engineering process is broken down into six component steps, each of which has an analogous counterpart in the science practices.

1. Ask questions to identify problems or needs.
   - Engineers figure out what problems or needs exist and if they are, in fact, genuine in nature, that is they are real problems and not assumed.
2. Ask questions about the criteria and constraints of the devices or solutions.
   - Engineers further investigate the nature of the problem or need they are attempting to solve in order to identify what scientific concepts will be applied, what limitations and constraints might affect the design of a solution or device, and what other parameters need to be accounted for in solving the problem or need.
3. Generate and communicate ideas for possible devices or solutions.
   - Engineers design and communicate proposed devices or solutions that they predict will address problem or need as defined by the identified constraints and criteria.
4. Build and test devices or solutions.
   - Engineers build and test full-scale prototypes or models of prototypes of devices that will meet the need or solve the problem. In the case of solutions, engineers test their proposed solutions or tests their solutions through the use of models. In both cases, the intent is to gather data to evaluate the effectiveness of their design.
5. Determine if the devices or solutions solved the problem and refine the design if needed.
   - Engineers analyze and interpret the test data to determine if their devices or solutions solved the problems or met the needs. If necessary, devices or solutions are refined based on the analysis of the data and tested again.
6. Communicate the results.
   - Engineers communicate the results of their design tests, using evidence to support claims that their design was effective at solving the problem or meeting the need.

The following table illustrates the relationship between the practices that scientists engage in and the practices that engineers engage in. Because these eight practices are analogous to one another and have already been described in detail in other sections of this work, that information is not reproduced here.

What Scientists Do	What Engineers Do
Ask Questions: Scientists ask questions about unknown phenomena in order to investigate and develop an understanding of the natural universe.	**Define Problems or Needs**: Engineers identify problems or needs in order to design, test. and refine possible solutions .
Develop and Use Models: Scientists develop and use models as a means to test and manipulate and communicate how natural phenomena and processes occur.	**Develop and Use Models:** Engineers develop and use models both to test and refine possible design solutions as well as to communicate successful designs.

Plan and Carry Out Investigations: Scientists plan and carry out investigations as a means to acquire data, both observations and measured, about natural phenomena.	**Plan and Carry Out Tests:** Engineers plan and carry out tests of proposed solutions and design in order to evaluate the efficacy of their designs.
Analyze and Interpret Data: Scientists analyze and interpret data acquired through investigation and experimentation in order to look of patterns, trends, outliers, etc… that can help determine a cause and effect relationship of a natural phenomenon or process.	**Analyze and Interpret Data:** Engineers analyze and interpret data acquired through tests of proposed designs or solutions in order to determine if their designs or solutions are successful at meeting the need or solving the problem.
Use Mathematics and Computational Thinking: Scientists apply math practices as part of the analysis and interpretation of data. Computational tools and thinking include the use of technologies, practices, and models to represent and manipulate complex, large data sets.	**Use Mathematics and Computational Thinking:** Engineers apply math practices as part of the analysis and interpretation of test data. Computational tools and thinking include the use of technologies, practices, and models to represent and manipulate complex, large data sets.
Construct Explanations: Scientists use evidence from investigations and scientific reasoning to construct explanations for natural phenomena and processes.	**Design Solutions:** Engineers use evidence from design tests and the application of scientific principles to design viable solutions to problems and needs.
Engage in Scientific Argument from Evidence: Scientists engage in scientific argument as a process of analyzing and interpreting data and apply scientific reasoning in making claims supported by evidence as well as analyzing alternate conclusions supported by data.	**Engage in Argument from Evidence:** Engineers engage in argument as a process of evaluating the efficacy of proposed solutions or designs as well as evaluating alternate designs and solutions to problems or needs.
Obtain, Evaluate, and Communicate Information: Scientists obtain scientific information to provide context for everything else they do. They evaluate sources of information, whether from texts or data, and they communicate information, claims, explanations, and models.	**Obtain, Evaluate, and Communicate Information:** Engineers obtain scientific information in order to apply scientific principles and concepts throughout the design process. They evaluate information use to support their designs as well as test data, and they communicate their designs through claims, proposals, and models.

For more details about the defining characteristics of each component of this practice, refer to the support documents for the specific practices identified above.

It is important to understand that science and engineering are not separate sets of practices. It is through the application of scientific concepts and principles that engineers determine the nature of human needs and problems, evaluate the criteria and limitations of problems and possible solutions, and ultimately develop solutions and devices that apply scientific concepts in a concrete manner that is used to solve problems and fulfill human needs. This is why performance indicators related to engineering are embedded within science content strands.

The goals for this practice are for students to apply scientific concepts and ideas to the solving problems or meeting needs. Students should define problems related to scientific concepts, design and test devices or solutions, and model and propose successful devices or solutions that reflect both an understanding of the underlying scientific concepts under study as well as how those concepts are applied in the solution of a problem or the design of a product that meets a need.

INSTRUCTIONAL GUIDANCE AND CONSIDERATIONS

Scope and Sequence: When to introduce an engineering challenge

Teachers should be aware that engineering performance tasks are likely to take a greater amount of instructional time to complete. Therefore, engineering problems are best introduced at the beginning of a unit of study. As the students learn about and investigate the science content developed in the unit of study, the teacher will direct them back to the engineering problem and how their new information might be applied to solving the problem or designing a solution. In this way, the content of the standard is appropriately addressed while the engineering performance indicator provides an authentic context for the application of the science concepts and understandings. Teachers who wait until the end of a unit of study to then introduce a design challenge as a project-based learning experience will find that their students will not have the time necessary to complete the task before the teacher needs to move on to the next unit of study.

It is essential for student to

- Understand that technological designs or products are produced by the application of scientific knowledge to meet specific needs of humans. The field of engineering focuses on these processes.
- Understand that there are four stages of technological design:
  - Problem identification
  - Solution design (a process or a product)
  - Implementation
  - Evaluation
- Understand that common requirements within the solution design stage of all technological designs or products include:
  - Cost effectiveness or lowest cost for production;
  - Time effectiveness or the least amount of time required for production
  - Materials that meet specific criteria, such as:
    - Solves the problem
    - Reasonably priced

    - Availability
    - Durability
    - Not harmful to users or to the environment
    - Qualities matching requirements for product or solution
    - Manufacturing process matches characteristics of the material
- Understand that benefits need to exceed the risk.
- Understand that there are tradeoffs among the various criteria. For example, the best material for a specific purpose may be too expensive.
- As the various components of this practice have been described elsewhere in terms of defining characteristics, instructional guidance, performance expectations, assessment tasks, etc., that information will not be reproduced here. Details for instructional guidance and considerations can be found for each subdivision of this practice in the support document for each specific practice.

EVIDENCE OF MASTERY

Students who show evidence of mastery in this practice will be able to:

- Define problems and needs.
- Describe the criteria and limitations of a problem or need.
- Design and propose possible solutions based on scientific thinking.
- Test designs/solutions.
- Analyze test data to determine if the design or solution was successful.
- Refine designs if necessary based on the outcome of design tests.
- Support claims made about designs based on evidence and scientific reasoning.
- Propose and communicate successful designs/solutions.
- Analyze and evaluate the designs/solutions of others.

PERFORMANCE TASK EXAMPLES

The following are selected examples of performance tasks aligned with sample grade band content standards and performance indicators. The purpose of these examples is to illustrate what a performance task would look like that meets the performance expectations of both a given content performance indicator and the science and engineering performance indicator. Examples of performance tasks that do not meet the criteria of the science and engineering performance indicator are also provided for comparison. This list does not provide examples for every grade level.

Grade	Subject	Example	Non-Example
K	Earth Science	Students plan an outdoor celebration. They define problems related to weather that might occur with an outdoor activity. They ask questions about possible constraints and criteria that will affect and/or limit possible devices or solutions. They brainstorm and communicate possible solutions or devices that can be used to solve the identified problems. Students then test devices or models of devices and/or justify solutions to weather-related problems. They analyze results of tests to determine if the solutions/devices solved the problem. Finally, students communicate the results.	Students identify possible problems from a given list and pick a solution from a prescribed set of possible solutions. Students justify the solution the teacher proposed. Teacher tells students how problems like this are solved.
3	Physical Science	Students are informed that their local zoo is going to build a new habitat for their penguins. Assuming the role of habitat designers, students ask questions about the problems or needs related to maintaining an ideal temperature in a penguin habitat. Students ask questions about criteria and constraints related to the design of a new habitat. Students generate and communicate ideas for possible habitat designs and build and test model habitats to acquire evidence needed to determine if the proposed habitat design is effective. Students refine their designs as necessary. Students communicate results.	Students are given a set of predetermined materials with instructions to build a model penguin habitat and will test predetermined outcomes. Teacher will provide an article about penguin habitats that students will read and discuss the article in terms of effective design.
High School	Biology	Students research topics related to human impacts on the biodiversity of an ecosystem. Based on their research, students generate questions about ecological problems related to the human impact on biodiversity. Students also ask questions about the constraints of possible solutions to human impact. Students generate and communicate ideas	Students build an ecosystem diorama. Students read about human impact on biodiversity and write a report or presentation to their class. Students tour immediate school ground to identify ecosystem components and local biodiversity.

		for possible solutions to minimize the impact of human activities on biodiversity of that ecosystem. Students justify their proposed solutions, supporting claims with scientific evidence from research and models, refining their solutions as needed. Students communicate their solutions as part of a proposal to minimize the human impact on the particular ecosystem.	