# NGSS Evidence Statements

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## Overview

The Next Generation Science Standards (NGSS) detail assessable performance expectations (PEs) — what students should be able to demonstrate at the end of instruction at each grade level or grade band, spanning kindergarten through high school. Each PE represents the integration of three "dimensions" of science education: scientific and engineering practices, disciplinary core ideas (DCIs), and crosscutting concepts (CCCs). Likewise, student proficiency on each PE is demonstrated by student performance on all three of these dimensions simultaneously. In other words, the hallmark of student proficiency is a three-dimensional performance in which the student uses a core idea, science and engineering practice, and crosscutting concept together to address a given context or phenomenon.

The NGSS integrate one component from each of the three dimensions detailed in the National Research Council (NRC)'s *A Framework for K–12 Science Education* to create each of the student PEs. The NGSS lists all of those component pieces in the foundation boxes underneath each PE in the NGSS architecture. As a result, the foundation boxes represent an initial level of "unpacking" of the PEs. However, the information in each foundation box is one-dimensional. Each box describes one of the dimensions from the *Framework* separately, but it provides limited details about what it looks like for students to integrate the dimensions into a three-dimensional student performance.

For example, NGSS performance expectation HS-PS1-1 has the following assessable component composed of the three dimensions from the foundation boxes below (the assessable component is color coded here to show the three different dimensions: blue = practices, orange = DCIs, and green = CCCs).

**HS-PS1-1**

Students who demonstrate understanding can:

**HS-PS1-1.** **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.**

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
|---|---|---|
| **Developing and Using Models**<br>• Use a model to predict the relationships between systems or between components of a system. | **PS1.A: Structure and Properties of Matter**<br>• Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.<br>• The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. | **Patterns**<br>• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. |

In an effort to describe more specifically what you would see in proficient student performance of the NGSS PEs, scientists and educators together developed **Evidence Statements** for every PE in every grade level. The evidence statements are intended to provide clear, measurable components that, if met, fully satisfy each PE described within the NGSS.

The evidence statements provide detail on how students will use the practices, crosscutting concepts, and disciplinary core ideas together in their demonstration of proficiency on the PEs by the end of instruction. The evidence statements are intended to better clarify what abilities and knowledge the students should be able to demonstrate **at the end** of instruction, without limiting or dictating instruction. The statements were written to allow for multiple methods and contexts of assessment, including assessing multiple related PEs together at the same time. This last concept refers to "bundling" PEs, which will be discussed more in a later section of this document.

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## Purpose of the Evidence Statements

The evidence statements, as described here, describe what teachers or assessors would observe (not infer) from successful student performance of each performance expectation (PE). The evidence statements can serve as supporting materials for the design of curriculum and assessments. In the NGSS, each PE is accompanied by a foundation box with associated practice, core idea, and crosscutting concept. The evidence statements expand this initial structure to include specific, observable components of student performance that would ***demonstrate integrated proficiency by using all of the necessary tenets of the practice to demonstrate understanding of the disciplinary core ideas (DCIs) through the lens of the crosscutting concepts (CCC).*** We hope that by providing these links among the practice, DCI, and CCC for each PE, educators and assessors will have a clearer idea about 1) how these dimensions could be assessed together, rather than in independent units or sections; 2) the underlying knowledge required for each DCI; 3) the detailed approaches to science and engineering practices; and 4) how crosscutting concepts might be used to deepen content- and practice-driven learning.

The evidence statements can be viewed as a magnification of the NGSS performance expectations. Imagine sliding a plant cross-section under a microscope; this will allow you to see greater detail and to develop a deeper understanding about how the component parts work together to make up the full plant. However, seeing this magnified view does not change the fundamental properties of the plant, nor does it give the plant new functions. Similarly, these evidence statements provide more detail about the PEs and their associated foundation boxes, but the evidence statements do not go beyond the scope of the PEs themselves. Therefore, the statements are more detailed guidelines that can be helpful for guiding assessment, describing what students should be able to demonstrate at the end of instruction. They are not curricula, and would not suffice as such; indeed, to achieve the proficiency described in the statements, students will need rich experiences with each of the three dimensions in multiple real-world contexts. The evidence statements are **not** intended to put limits on student performance or instructor design; instead, the statements detail the minimum proficiency requirements for student understanding and performance described in each PE. The methods and resources used to help students build toward proficiency and beyond are left to educators' discretion.

It is important to note that "minimum proficiency" on the NGSS PEs looks different than did proficiency on most previous sets of standards. The NGSS PEs were designed to be very cognitively demanding, so student proficiency will require a higher level of rigor (for example, a higher Depth of Knowledge [DOK] or Bloom's Taxonomy Level) than did most previous sets of state science standards. Minimum proficiency on each NGSS PE is described by the associated evidence statements.

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## Structure of the Evidence Statements

All NGSS performance expectations are three dimensional. They all describe ways that students can demonstrate their understanding of content and concepts by using a science or engineering practice. Therefore the practices provide the means by which students can make their thinking visible. Likewise, the evidence statements were developed using the science and engineering practice as the organizing structure, as this is the dimension that structures student performance. As stated in the *Framework,* "Participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary core ideas of science and engineering; moreover, it makes students' knowledge more meaningful and embeds in more deeply into their worldview." This does not mean the practices are more important than the other dimensions — only that they provide the framework for the performance. The general templates (described below) for each practice used to organize the evidence statements are listed in the Appendix of this document, and all use the general heading "Observable Features of the Student Performance". These templates were made in consultation with science education researchers[1] who have focused their research on the practices of science. With their insight, each practice has a set of categories that allow for a more coherent structure of the Evidence Statements and provide more detail on how to identify three dimensional learning.

For example, all parts of performance expectation HS-PS1-1 (shown in the overview) were used to develop the following evidence statements (here, color coded to show the three different dimensions: blue = practices, orange = DCIs, and green = CCCs).

| Observable features of the student performance by the end of the course: | | | |
|---|---|---|---|
| 1 | Components of the model | | |
| | a | **From the given model**, students **identify and describe the components of the model that are relevant for their predictions, including:** | |
| | | **i.** | **Elements and their arrangement in the periodic table;** |
| | | **ii.** | **A positively-charged nucleus composed of both protons and neutrons, surrounded by negatively-charged electrons;** |
| | | **iii.** | **Electrons in the outermost energy level of atoms (i.e., valence electrons); and** |
| | | **iv.** | **The number of protons in each element.** |
| 2 | Relationships | | |
| | a | Students **identify and describe the relationships between components in the given model, including:** | |
| | | i. | **The arrangement of the main groups of the periodic table reflects the patterns of outermost electrons.** |
| | | **ii.** | **Elements in the periodic table are arranged by the numbers of protons in atoms.** |
| 3 | Connections | | |
| | a | Students **use the periodic table to predict the patterns of behavior of the elements based on the attraction and repulsion between electrically charged particles and the patterns of outermost electrons that determine the typical reactivity of an atom.** | |

[1] Mayer, K. & Krajcik, J. (2015 – in press). Designing and Developing Scientific Modeling Tasks. In R.F. Gunstone (ed.) *Encyclopedia of Science Education*, Dordrecht: Springer, pages 293-299.

| | | | |
|---|---|---|---|
| | b | Students predict the following patterns of properties: | |
| | | **i.** | **The number and types of bonds formed (i.e. ionic, covalent, metallic) by an element and between elements;** |
| | | **ii.** | **The number and charges in stable ions that form from atoms in a group of the periodic table;** |
| | | iii. | **The trend in reactivity and electronegativity of atoms down a group, and across a row in the periodic table, based on attractions of outermost (valence) electrons to the nucleus; and** |
| | | iv. | **The relative sizes of atoms both across a row and down a group in the periodic table.** |

The blue practice language is generally found in the top-level bullets in each category, whereas the orange DCI and green CCC language is usually concentrated in the detailed category bullets. The template category names are in shaded gray boxes to indicate that they represent part of the organization of the statements rather than part of the student performance.

Appendix F of the NGSS describes what students should know and be able to do in reference to each of the eight practice categories in each grade band. Within each general practice category, there are many different practice "elements" or component parts. These component parts are what were used by the NGSS writers as they developed the NGSS performance expectations (PEs), and therefore different PEs within the same practice category often focus on a slightly different aspect of that practice. Likewise, the evidence statements use only the parts of each practice template that are appropriate to describe the particular practice element used in that PE. This means that the templates in the Appendix won't necessarily align in their entirety with a particular set of evidence statements (for example, the practice language in the example above is not identical to the Appendix's Developing and Using Models template). The templates describe only the general observable features of each practice, and only for the end of grade 12. Specifics of individual practice elements as they relate to a PE, as well as different levels of practices for each grade band, can be found within an individual set of evidence statements.

One common misconception about NGSS and potentially about the Evidence Statements is that they describe teacher practice. In reality, both the NGSS and the Evidence Statements describe student performances, and because of this, the evidence statements are written in active voice to be clear about what **students** should be able to do. The statements do not describe teacher prompts or instructional techniques. For example, the evidence statements for PEs that use the "constructing explanations" practice ask students to "articulate the explanation". This doesn't mean that the **teacher** should give the students the explanation. Rather, this is the indicator that a teacher or scorer would look for to see if the student demonstrated an ability to construct an explanation about a given disciplinary core idea. If the PE requires a student to construct an explanation, having the teacher give the explanation to the student fundamentally changes the performance expectation.

It is important to note that the templates used in this document are simply the categories under which educators can describe all of the things students would need to demonstrate to show that they are proficient on a performance expectation. **The templates and categories are <u>not</u> intended to be used in any of the following ways:**

- As descriptions of increasing levels of cognitive difficulty, Depth of Knowledge levels, or varying levels of student proficiency (e.g., using the first category as the least difficult or first stepping stone for developing student proficiency). In reality, **all** features of the evidence statements would have to be observed to infer that a student is proficient on a performance expectation, and there is no intended ordering within the categories.
- As a checklist that denotes the ordering of steps in a student's performance. In reality, while some student performances would have a logical order, the order for others would depend on the context of an assessment. For example, in the Constructing Explanations template, the first bullet is "articulating the explanation," which could be a culminating student performance.
- As instructional strategies or steps in a classroom activity. In reality, instruction to help students build towards any one of the performance expectations would require many activities that engage students in many different practices and many different instructional strategies.

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## How Evidence Statements Can Be Used

*Audience*

Many different types of audiences will be able to make use of the evidence statements in different ways, so use is not restricted to only certain audiences. However, all audiences should have at least one thing in common: a deep prior understanding of the NGSS and of the NRC's Framework for K-12 Science Education, on which the NGSS was based. Understanding the content and vision of these two documents is a prerequisite for successful application of the evidence statements, whether for assessment or instructional purposes.

*Assessment*

The evidence statements are designed to provide more guidance on what a student could do to demonstrate that he or she is proficient on the NGSS PEs. The statements can be most directly useful when designing summative assessments (either classroom or large-scale), as they provide a starting point for describing student proficiency at the end of instruction.

To use the evidence statements in directly guiding assessment, they will need to be tailored to the specific examples or prompts within the context of the assessment item being created. For example, the Evidence Statements section of the Classroom Sample Assessment Tasks shows the content and format of the NGSS Evidence Statements but with the context of each sample assessment task (including the Common Core State Standards mathematics content and practices). The NGSS evidence statements also can guide the development of a "proficient" level of a rubric, but they would similarly need to be tailored to the context of the assessment. Also, rubrics for other performance levels (e.g., advanced, basic) should be created that align with the specific context of the assessment.

In addition, as described in the 2014 NRC report "Developing Assessments for the Next Generation Science Standards", the NGSS PEs should not be assessed discretely or one-at-a-time. Assessment developers will likely assess "bundles" (groups) of multiple related PEs or multiple parts of PEs at a time. For example, assessment tasks could simultaneously assess student proficiency on HS-LS2-1, HS-LS2-2, and HS-LS2-6. In this example, the evidence statements for these three PEs could be combined to avoid repetition of information (e.g., the data on numbers and types of organisms and the focus on ecosystems, changes in ecosystems, and factors affecting the ecosystems) and to strengthen the connections between the different core ideas. Likewise, the ETS1 (Engineering, Technology, and Applications of Science) PEs should always be bundled together with science PEs to plan instruction and assessment; they are never meant to stand alone. Whenever PEs are bundled for instruction or assessment planning purposes, the associated evidence statements also should be considered together in a bundle.

### *Instruction*

If the evidence statements are used in support of instructional design, it is important to keep in mind that the statements detail what students should be able to do **at the end** of instruction. There are numerous pathways educators may use across the course of lessons and units to prepare students for success on the performance expectations (and thus to be able to demonstrate the evidence statements by the end of a unit, course, or year). It is important to note that the NGSS PEs and the corresponding evidence statements are **not** a substitute for day-to-day lesson goals that drive the learning process. These lesson-level goals (and indeed the lessons themselves) would still be three-dimensional (i.e., each contain a practice, a DCI, and a CCC), but they would likely engage students in many different practices along with a piece of the DCI(s) and CCC(s) under study. In this way, educators can plan instructional sequences that use all of the NGSS practices working together over the course of a year to help students reach proficiency on all of the performance expectations for that grade level.

Although evidence statements are listed individually for each performance expectation, this does **not** indicate that they should be measured individually, or that performance expectations should be taught or assessed individually. Classroom instruction will often be focused on helping students build towards several different performance expectations at one time because so many concepts and practices are naturally interrelated. When students are learning about photosynthesis, for example, they have to first learn about atoms and energy. Therefore instructional sequences that are building towards HS-PS1-2 and HS-PS1-4 also are helping to build student understanding towards HS-LS1-5 and HS-LS1-6. By identifying the inherent relationships among different PEs, "bundling" will help students build a deeper understanding of concepts, and will also save a significant amount of instructional time when compared to teaching toward each PE individually.

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## Limitations of the Evidence Statements

Evidence statements are a guide for and can inform instruction and assessment. While they provide guidance for how the material in the foundation boxes are combined to define proficiency of student performance on the PEs, they do not provide or proscribe the contexts through which the PEs may be taught or assessed, the rubrics on which levels of student success would be measured, the sequence of instruction or assessment, or the limits on student learning.

The vision of the NRC *Framework* as well as the NGSS is that students develop critical science and engineering skills and knowledge to effectively interact with and explain phenomena they encounter within the context of the real world. To really demonstrate the vision and spirit of the NGSS, the PEs alone (and therefore, the evidence statements) are not enough, because they do not specify a thematic or phenomenon-based context. In other words, they do not give students a specific reason or application for the knowledge, leaving that up to specific curricular and assessment contexts. For example, we can consider HS-PS1-1; although the PE itself demands a rigorous and sophisticated knowledge base across all three dimensions, there is no mention of *why* or *in what type of specific situation* students would need to explore patterns in the periodic table. Without this context, it would be difficult to understand the value of being able to demonstrate that knowledge, and indeed, there are many diverse contexts in which the PE could be applied. Because the evidence statements are written to provide more clarity about what the PEs ask students to demonstrate, these statements are **not sufficient to replace lesson plans or assessment items**; asking students to simply perform the PEs verbatim would not be useful for instruction or assessment. Specific contexts allow for diversification and ingenuity in instruction and assessment, and allow students to be able to demonstrate their knowledge across multiple PEs, using the appropriate practices, DCIs, and CCCs that the situation calls for.

Although evidence statements could serve as the starting point for creating rubrics to assess student responses, they are **not complete scoring rubrics** themselves. For example, some criteria are not specified in the statements but are assumed for all proficient student performance and would be specified in grading rubrics, such as that the student responses should be scientifically accurate (at a grade-appropriate level) and should be clearly communicated with complete sentences where appropriate. Other rubric performance levels also are not included, such as what student responses would look like at an "advanced" level or at a level below proficiency. Additionally, assessment rubrics would need to be contextualized to the actual prompts or examples used in the question or task.

Like the NGSS performance expectations themselves, the evidence statements are **not limits on student coursework**. They merely describe student proficiency on the NGSS PEs. Students may be taught material that goes beyond the evidence statements, and they are encouraged to take courses that go beyond the NGSS expectations. Another resource, the Accelerated Model Course Pathways, will soon be released to describe how courses can be arranged in middle and high school to ensure that students have myriad opportunities to take advanced and Advanced Placement (AP) science coursework in high school. For more information, see www.nextgenscience.org/resources.

It also is important to note that, although the evidence statements are numbered, the numbers **do not indicate a sequence** to instruction or assessment, and they also **do not indicate different**

**DOK levels**. The numbers only serve to provide labels for each line for easy reference, e.g., to be able to name MS-PS1-1 evidence statement 2.a.i.

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## Development Process and Criteria

To write the evidence statements, discipline-based teams of scientists and educators — including many of the writers of the NGSS — worked together to create drafts of the statements for each performance expectation, beginning with high school. Additional educators, assessment experts, and disciplinary specialists then gave feedback after each round of review.

During the development process, the writers and reviewers created and then used the following decision rules and criteria for the evidence statements. The use of common criteria by the different writing teams allowed for a more consistent end product.

Guiding Principles

- The statements should describe observable evidence that a scorer or assessor could actually see and measure, not descriptions of students' intent or mental processes. In writing the statements, you should consider how a student demonstrates that they have considered evidence and other viewpoints, for example.
- Evidence statements should be written as if they are the "proficient" level of a scoring rubric (although without the context of the specific instruction or assessment task). Therefore, a student would have to demonstrate **all** of the evidence statements in order to be graded as "proficient" on that performance expectation. (Note that it is likely that there would not be a one-to-one correlation between assessment items and PEs. For example, some of the evidence statements under one PE might be elicited by one performance task and the rest might be elicited by an essay question.)
- The statements should be detailed and specific enough to allow a scorer to identify the specific performances associated with proficiency on the PE (versus "advanced" or "basic" level performances. Advanced performance might require student performance that exceeds the proficient level, for example perhaps by synthesizing additional sources of evidence, going to the next grade band up in the progressions matrices for one of the three dimensions, or making connections between different disciplines). It is important to note that the proficiency level for the NGSS is higher than for most previous standards — that is, the NGSS is more cognitively demanding — so proficiency on old versus new standards will not look the same.

Content of the Evidence Statements

- The foundation box bullets **from all three dimensions** (i.e., the practices, DCIs, and CCCs) — not just the wording of the PEs/assessable components — should be used as the foci of the evidence statements. For example, include statements of evidence that address material contained in the individual bullets of the practices, DCIs, and CCCs foundation boxes that might not be explicit in the PE.

- Specific mathematical formulae should be called out in the statements whenever they are required for proficient student performance on the PE, and the purpose of including the formula should be explicit (e.g., whether students are deriving the formula or whether the formula is given and should be used by the students).
- The evidence statements should be three-dimensional whenever possible so that the practices, DCIs, and CCCs are all framed in the context of one another. For example, "The model illustrates the interactions between…"
- The evidence statements should not contain content or context beyond what is included or implied in the DCI or PE. The evidence statements need to be useful in many different instructional or assessment contexts, so specific contexts will need to be added by the end user when the evidence statements are applied to instruction and assessment. In the evidence statements themselves, only details that are absolutely necessary to understand the most narrow interpretation of the DCI and PE should be included in the statements.
- The evidence statements should not contain content or context beyond what is included or implied in the specific practices and CCC bullets in the foundation boxes. For example, if a performance expectation calls for students to "carry out an investigation," then the evidence statements should not require students to also plan the investigation.
- The evidence statements should convey the **intent** of the PE in the context of the foundation boxes. For example, in HS-LS1-1, the PE includes the words "the structure of DNA," but the associated DCIs make clear that the intent is not for students to memorize facts about chromatin structure or even double helices — the "structure" referred to here is simply "genes."
- Content from the clarification statements can be considered as follows:
  - "Emphasis statements" should inform the evidence statements, as they convey the intent of the PE.
  - "Examples" from the clarification statements should not be *required* by the evidence statements — but can be included purely as examples — because the evidence statements need to be useful in many different instructional and assessment contexts.
- The assessment boundaries should be considered when writing evidence statements. The assessment boundaries provide limits for large-scale summative assessment of each PE. Because the evidence statements could be used to describe successful student performance in any kind of assessment of the PE (formative or summative, at a small or large scale), the assessment boundaries should be taken into account in the evidence statements. (Note that instruction can certainly go beyond the boundaries of the evidence statements, just as it can go beyond the boundaries of the PEs.)
- Concepts that are included in prior grades' DCIs should not be repeated unless they are also in the current grade's DCIs. For example, the evidence statements for MS-ESS2-4

should not include stating where water might be found (which is covered by 2-ESS2-3) or how much water can be found in each place (which is covered by 5-ESS2-2).

Stylistic Principles Guiding the Development

- Practice language templates should be used as much as possible.
- Each word should be very thoughtfully chosen to avoid ambiguity and to convey precise meaning.
- Words like “describe” should be used instead of “mention” or “discuss” to avoid prescription of an oral presentation.
- Anything with a plural requirement should specify the minimum number required.
- Words like “accurately” and “correctly” are implied; they do not need to be repeated for each statement.
- Words like “and” versus “or” should be used very carefully and their intended use should be made explicit in the statements.
- Statements that contain multiple lists of required content should be parsed into separate bullets.
- Words like “explain” and “explanation” should be used carefully to avoid confusion with the practice of “constructing explanations.” In many cases, something like “describe” or “description” is more accurate.

Vocabulary Use in the Statements

- Words from the foundation boxes or PEs can be used.
- Because everything in the evidence statements is required, unnecessary vocabulary should not be introduced. Instruction can go beyond the evidence statements to introduce additional vocabulary.
- Additional scientific words can be used **if they are absolutely required** to understand the big concept/core idea.

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| | |
|---|---|
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# Appendix

The NGSS are composed of three dimensions: science and engineering practices, disciplinary core ideas (DCIs), and crosscutting concepts (CCCs). All three dimensions are equally important in a student's science education and are detailed extensively in the NRC *Framework* and in the NGSS appendices. In the structure of each NGSS student performance expectation (PE), the practice dimension provides the means by which students outwardly demonstrate the performance expectations and therefore demonstrate their understanding of the content and concepts. Therefore when developing the NGSS Evidence Statements, the writers built on the work of Mayer and Krajcik (2015 – in press) and used the practices to create an organizing structure for each set of statements.

The general organizing structure created by each practice is listed in this appendix, describing observable features of student performance of decontextualized practices by the end of 12th grade. However, when the practices are contextualized in individual PEs and when different "practice elements" (bullets from Appendix F of the NGSS) are used in each PE, the specific words and categories used to structure the evidence statements often change. Therefore the specifics of individual practice elements, as well as different levels of practices for different grade bands, can be found within each individual set of evidence statements. In addition, when the K–8 evidence statements are released, this appendix may be updated or accompanied by similar template structures for the practices at the different grade bands.

Although the DCIs and CCCs are not included in this appendix, Appendix G of the NGSS describes details of CCC expectations for students in each grade band, and Appendix E of the NGSS describes summaries of DCI progressions across the grade bands. The full text of the DCIs in every grade band can be found in the NRC *Framework*.

*General observable features of the practices by the end of 12th grade.*

**Asking Questions and Defining Problems**

I. Asking questions
    1. Addressing phenomena or scientific theories
        a. Students formulate specific questions based on examining models, phenomena, or theories.
        b. Students' questions could generate answers that would clarify the relationships between components in a system.
    2. Empirical testability
        a. Students' questions are empirically testable by scientists.

II. Evaluating questions
    1. Addressing phenomena or scientific theories
        a. Students evaluate questions in terms of whether or not answers to the questions would provide relevant information about the targeted phenomenon in a given context.
    2. Evaluating empirical testability
        a. Students' evaluations of the questions include a description of whether or not answers to the questions would be empirically testable by scientists.

III. Defining problems
    1. Identifying the problem to be solved

a. Students' analyses include:
    i. A description of the challenge with a rationale for why it is a major global challenge;
    ii. A qualitative and quantitative description of the extent and depth of the problem and its major consequences to society and/or the natural world on both global and local scales if it remains unsolved; and
    iii. Documented background research on the problem from two or more sources, including research journals.

2. Defining the process or system boundaries, and the components of the process or system
    a. Students' analyses include identification of the physical system in which the problem is embedded, including the major elements and relationships in the system and boundaries so as to clarify what is and is not part of the problem.
    b. Students' analyses include a description of societal needs and wants that are relative to the problem (e.g., for controlling $CO_2$ emissions, societal needs include the need for cheap energy).
3. Defining the criteria and constraints
    a. Students specify the qualitative and quantitative criteria and constraints for acceptable solutions to the problem.

**Developing and Using Models**

I. Using either a developed or given model to do the following:
    1. Components of the model
        a. Students define and clearly label all of the essential variables or factors (components) within the system being modeled.
        b. When appropriate, students describe the boundaries and limitations of the model.
    2. Relationships
        a. Students describe the relationships among the components of the model.
    3. Connections
        a. Students connect the model to causal phenomena or scientific theories that students then describe or predict, using logical reasoning.

II. Developing a Model: Students develop a model with all of the attributes above

**Planning and Carrying Out Investigations**

1. Identifying the phenomenon to be investigated
    a. Students describe the phenomenon under investigation, question to be answered, or design solution to be tested.
2. Identifying the evidence to answer this question
    a. Students develop a plan for the investigation that includes a description of the evidence to be collected.
    b. Students describe how the evidence will be relevant to determining the answer.
3. Planning for the investigation
    a. Students include in the investigation plan a means to indicate, collect, or measure the data, including the variables to be tested or controlled.
    b. Students indicate whether the investigation will be conducted individually or collaboratively.
4. Collecting the data
    a. Students perform the investigation, collecting and recording data systematically.

5. Refining the design
    a. Students evaluate the accuracy and precision of the data collected.
    b. Students evaluate the ability of the data to be used to answer the question.
    c. If necessary, students refine the investigation plan to produce more accurate and precise data.

**Analyzing and Interpreting Data**

1. Organizing data
    a. Students organize data to represent phenomena.
    b. Students clearly describe what each data set represents.
2. Identifying relationships
    a. Students analyze data using appropriate tools, technologies, and/or models and describe observations that show a relationship between quantities in the data.
3. Interpreting data
    a. Students interpret patterns in the data and use them to describe and/or predict phenomena.
    b. Students include a statement regarding how variation or uncertainty in the data (e.g., limitations; accuracy; any bias in the data resulting from choice of sample, scale, instrumentation, etc.) may affect the interpretation of the data.

**Using Mathematical and Computational Thinking**

I. Using Given Mathematical or Computational Representations: Using either developed or given mathematical or computational representations to do the following:
    1. Representation
        a. Students clearly define the system that is represented mathematically.
        b. Students clearly define each object or quantity in the system that is represented mathematically, using appropriate units.
        c. Students identify the mathematical claim.
    2. Mathematical or computational modeling
        a. Students use mathematical or computational representations (e.g., equations, graphs, spreadsheets, computer simulations) to depict and describe the relationships between system components.
    3. Analysis
        a. Students analyze the mathematical representations, use them to support claims, and connect them to phenomena or use them to predict phenomena.

II. Developing Mathematical or Computational Representations: Students develop mathematical or computational representations with all of the attributes above

**Constructing Explanations and Designing Solutions**

I. Constructing explanations
    1. Articulating the explanation of phenomena
        a. Students clearly articulate the explanation of a phenomenon, including a grade-appropriate level of the mechanism involved.
    2. Evidence
        a. Students cite evidence to support the explanation. The evidence can come from observations, reading material, or archived data. The evidence needs to be both appropriate and sufficient to support the explanation.

3. Reasoning
    a. Students describe the reasoning that connects the evidence to phenomena, tying in scientific background knowledge, scientific theories, or models.
4. Revising the explanation (as necessary)
    a. Given new evidence or context, students construct a revised or expanded explanation.

II. Designing solutions
1. Using scientific knowledge to generate the design solution
    a. Students restate the original complex problem into a set of two or more sub-problems.
    b. For at least one of the sub-problems, students propose two or more solutions.
    c. Students describe the scientific rationale for each solution, including choice of materials and structure of the device where appropriate.
    d. If the students propose solutions for more than one sub-problem, they describe how the solutions to the sub-problems are interconnected to solve all or part of the larger problem.
2. Describing criteria and constraints, including quantification when appropriate
    a. Students describe criteria and constraints for the selected sub-problem(s).
    b. Students describe the rationale for which criteria should be given highest priority if tradeoffs must be made.
3. Evaluating potential solutions
    a. Students evaluate the solution(s) to a complex real-world problem systematically, including:
        i. Analysis (quantitative where appropriate) of the strengths and weaknesses of the solution with respect to each criterion and constraint, as well as social and cultural acceptability, and environmental impacts;
        ii. Consideration of possible barriers to implementing each solution, such as cultural, economic, or other sources of resistance to potential solutions; and
        iii. An evidence-based decision of which solution is optimum, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution, and barriers to be overcome.
4. Refining and/or optimizing the design solution
    a. Students refine or optimize the solution(s) based on the results from the evaluation.

**Engaging in Argument from Evidence**

I. Constructing arguments and evaluating given claims or design solutions
1. Identifying the given claims or design solutions
    a. Students identify the given claims, explanations, or design solutions to be evaluated, supported, or refuted with argumentation.
2. Identifying scientific evidence
    a. Students identify multiple lines of scientific evidence that is relevant to a particular scientific question or engineering design problem.
3. Evaluating and critiquing evidence: identification of the strength of the evidence used to support an argument for or against a claim or a particular design solution
    a. Students assess the validity, reliability, strengths, and weaknesses of the chosen evidence along with its ability to support logical and reasonable arguments about the claims, explanations, or design solutions.
4. Reasoning/synthesis: synthesizing the evidence logically and connecting to phenomena

a. Students synthesize the evidence logically and make explicit connections to known scientific theories or models.
b. Students develop an argument that explicitly supports or refutes the given claim, explanation, or design solution using the evidence and known scientific information.

II. Evaluating given evidence and/or reasoning
1. Identifying the given claims and associated evidence and/or reasoning
a. Students clearly identify the given claims or explanations.
b. Students clearly identify the given evidence that supports or refutes the given claims or explanations.
c. Student clearly identify the given reasoning that supports or refutes the given claims or explanations.
2. Identifying any potential additional evidence that is relevant to the evaluation
a. Students identify additional evidence, scientific theories, or models that were not given to the student.
3. Evaluating and critiquing
a. Students use the additional (not given) evidence to assess the validity and reliability of the given evidence along with the ability of the given evidence to support or refute the claims or explanations.
b. Students evaluate the logic of the given reasoning.

**Obtaining, Evaluating, and Communicating Information**

I. Obtaining information
1. Students obtain information from published material appropriate to the grade level.
2. Students compare and coordinate information presented in various modes (e.g., graphs, diagrams, photographs, text, mathematical, verbal).

II. Evaluating information
1. Students analyze the validity and reliability of each source of information, comparing and contrasting the information from various sources.
2. Students analyze the information to determine its meaning and relevance to phenomena.

III. Communicating information
1. Communication style and format
a. Students communicate information using at least two different formats (e.g., oral, graphical, textual, mathematical).
b. Students use communication that is clear and effective with the intended audience(s).
2. Connecting the Disciplinary Core Ideas (DCIs) and the Crosscutting Concepts (CCC)
a. Students' communication includes clear connections between the targeted DCIs and the targeted CCCs in the context of a specific question, phenomenon, problem, or solution.