**SEP (Science and Engineering Practices)**

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*](http://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts) 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 CO2 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.