Asking Questions and Defining Problems

Summary: Students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. For engineering, they should ask questions to define the problem to be solved and to elicit ideas that lead to the constraints and specifications for its solution (NRC Framework 2012, p. 56). Video summarizing Asking Questions and Defining Problems.

Elements of Asking Questions and Defining Problems:

- ✓ Ask questions
  - ➢ that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
  - ➢ to identify and/or clarify evidence and/or the premise(s) of an argument.
  - ➢ to determine relationships between independent and dependent variables and relationships in models.
  - ➢ to clarify and/or refine a model, an explanation, or an engineering problem.
  - ➢ that require sufficient and appropriate empirical evidence to answer.
  - ➢ that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.
  - ➢ that challenge the premise(s) of an argument or the interpretation of a data set.
- ✓ Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Developing and Using Models

Summary: Modeling can begin in the earliest grades, with students' models progressing from concrete "pictures" and/or physical scale models (e.g., a toy car) to more abstract representations of relevant relationships in later grades, such as a diagram representing forces on a particular object in a system (NRC Framework, 2012, p. 58). Video summarizing Developing and Using Models.

Elements of Developing and Using Models:

- ✓ Evaluate limitations of a model for a proposed object or tool.
- ✓ Develop or modify a model— based on evidence – to match what happens if a variable or component of a system is changed.
- ✓ Use and/or develop a model of simple systems with uncertain and less predictable factors.
- ✓ Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.
- ✓ Develop and/or use a model to predict and/or describe phenomena.
- ✓ Develop a model to describe unobservable mechanisms.
- ✓ Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Planning and Carrying Out Investigations

Summary: Students should have opportunities to plan and carry out several different kinds of investigations during their K-12 years. At all levels, they should engage in investigations that range from those structured by the teacher—in order to expose an issue or question that they would be unlikely to explore on their own (e.g., measuring specific properties of materials)— to those that emerge from students' own questions (NRC Framework, 2012, p. 61). Video summarizing Planning and Carrying Out Investigations.

Elements of Planning and Carrying Out Investigations:

- ✓ Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- ✓ Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- ✓ Evaluate the accuracy of various methods for collecting data.
- ✓ Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
- ✓ Collect data about the performance of a proposed object, tool, process or system under a range of conditions.

Analyzing and Interpreting Data

Summary: Once collected, data must be presented in a form that can reveal any patterns and relationships and that allows results to be communicated to others. Because raw data as such have little meaning, a major practice of scientists is to organize and interpret data through tabulating, graphing, or statistical analysis. Such analysis can bring out the meaning of data—and their relevance—so that they may be used as evidence.

Engineers, too, make decisions based on evidence that a given design will work; they rarely rely on trial and error. Engineers often analyze a design by creating a model or prototype and collecting extensive data on how it performs, including under extreme conditions. Analysis of this kind of data not only informs design decisions and enables the prediction or assessment of performance but also helps define or clarify problems, determine economic feasibility, evaluate alternatives, and investigate failures (NRC Framework, 2012, p. 61-62). Video summarizing Analyzing and Interpreting Data.

Elements of Analyzing and Interpreting Data:

- ✓ Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- ✓ Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- ✓ Distinguish between causal and correlational relationships in data.
- ✓ Analyze and interpret data to provide evidence for phenomena.
- ✓ Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.
- ✓ Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
- ✓ Analyze and interpret data to determine similarities and differences in findings.
- ✓ Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

Using Mathematics and Computational Thinking

Summary: Although there are differences in how mathematics and computational thinking are applied in science and in engineering, mathematics often brings these two fields together by enabling engineers to apply the mathematical form of scientific theories and by enabling scientists to use powerful information technologies designed by engineers. Both kinds of professionals can thereby accomplish investigations and analyses and build complex models, which might otherwise be out of the question (NRC Framework, 2012, p. 65). Video summarizing Using Mathematics and Computational Thinking.

Elements of Using Mathematics and Computational Thinking:

- ✓ Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends.
- ✓ Use mathematical representations to describe and/or support scientific conclusions and design solutions.
- ✓ Create algorithms (a series of ordered steps) to solve a problem.
- ✓ Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
- ✓ Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.

Note, the mathematics that students should be using in grades 6-8 is the New Jersey Student Learning Standards for Mathematics.

Constructing Explanations (for science) and Designing Solutions (for engineering)

Summary: "The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories" (NRC Framework, 2012, p. 52). Video summary of Constructing Explanations and Designing Solutions.

Elements of Constructing explanations (for science) and designing solutions (for engineering)

- ✓ Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- ✓ Construct an explanation using models or representations.
- ✓ Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
- ✓ Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events.
- ✓ Apply scientific reasoning to show why the data or evidence is adequate.
- ✓ Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.
- ✓ Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
- ✓ Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing for the explanation or conclusion

Engaging in Argument from Evidence

Summary: The study of science and engineering should produce a sense of the process of argument necessary for advancing and defending a new idea or an explanation of a phenomenon and the norms for conducting such arguments. In that spirit, students should argue for the explanations they construct, defend their interpretations of the associated data, and advocate for the designs they propose (NRC Framework, 2012, p. 73). Video summary of Engaging in Argument from Evidence.

Elements of Engaging in Argument from Evidence:

- ✓ Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.
- ✓ Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
- ✓ Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- ✓ Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.
- ✓ Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Obtaining, Evaluating, and Communicating Information

Summary: Any education in science and engineering needs to develop students' ability to read and produce domain-specific text. As such, every science or engineering lesson is in part a language lesson, particularly reading and producing the genres of texts that are intrinsic to science and engineering (NRC Framework, 2012, p. 76). Video summary of Obtaining, Evaluating, and Communicating Information.

Elements of Obtaining, Evaluating, and Communicating Information:

- ✓ Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).
- ✓ Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings.
- ✓ Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.
- ✓ Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts.
- ✓ Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.