Arizona Science Standards Science and Engineering Practices for 6-8 | For use with Arizona Science Standards

Asking Questions and Defining Problems

A science practice is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.

- Ask questions that arise from careful observation of phenomena, models, or unexpected results.
- Ask questions to clarify or identify evidence and the premise(s) of an argument.
- Ask questions to determine relationships between independent and dependent variables.
- Ask questions that challenge the interpretation of a data set.
- Ask questions to clarify and refine a model, an explanation, or an engineering problem.
- 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.
- Formulate a question that can be investigated within the scope of the classroom, school laboratory, or field with available resources and, when appropriate, frame a hypothesis (a possible explanation that predicts a particular and stable outcome) based on a model or theory.

Using Mathematics and Computational Thinking

Mathematics and computation are fundamental tools for representing physical variables and their relationships in both science and engineering.

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

Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate.

- Communicate scientific information and/or technical information (e.g. about a proposed object, tool, process, system) in different formats (e.g., verbally, graphically, textually, and mathematically).
- Gather, read, and communicate information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used.
- Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions that appear in scientific and technical texts in light of competing information or accounts; provide an accurate summary of the text distinct from prior knowledge or opinions.
- Critically evaluate whether or not technical information on a device, tool or process is relevant to its suitability to solve a specific design problem.

Constructing Explanations and Designing Solutions

The goal of science is the construction of theories that provide explanatory accounts of the world. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world.

- Construct explanations for either qualitative or quantitative relationships between variables.
- Apply scientific reasoning to show why the data are adequate for the explanation or conclusion.
- Base explanations on evidence obtained from sources (including their own experiments) and the assumption that natural laws operate today as they did in the past and will continue to do so in the future.
- Undertake design projects, engaging in the design cycle, to construct and implement a solution that meets specific design criteria and constraints.
- Apply scientific knowledge and evidence to explain real-world phenomena, examples, or events.
- Construct explanations from models or representations.
- Apply scientific knowledge to design, construct, and test a design of an object, tool, process or system.
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting.

Engaging in Argument from Evidence

Reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem in science and engineering.

- Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation for a phenomenon or a solution to a problem.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.
- Respectfully provide and receive critiques on scientific arguments by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
- Compare two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.
- 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.

The elements are not to be used as a check-off list, but rather a useful tool to help educators identify the specific pieces of knowledge and skill that make up the practice, crosscutting concept, or core idea at that grade-band.

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Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning. Engineering investigations include analysis of data collected in the tests of designs.

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

Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations.

- Use and/or develop models to predict, describe, support explanations, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.
- Develop models to describe unobservable mechanisms.
- Modify models—based on their limitations—to increase detail or clarity, or to explore what will happen if a component is changed.
- Use and develop models of simple systems with uncertain and less predictable factors.
- Develop a model that allows for manipulation and testing of a proposed object, tool, process or system.
- Evaluate limitations of a model for a proposed object or tool.

Planning and Carrying Out Investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually.

- Conduct an investigation and evaluate and revise the experimental design to ensure that the data generated can meet the goals of the experiment.
- Design 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 much data are needed to support their claim.
- Evaluate the accuracy of various methods for collecting data.
- Collect data and generate 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.

Arizona Science Standards Crosscutting Concepts for 6-8 | For use with Arizona Science Standards

Patterns

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
- Patterns can be used to identify cause and effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.
  - How do you describe the pattern?
  - How can you use this pattern in an explanation?
  - Is there a way to use mathematics to describe the pattern?
  - What predictions are possible based on the pattern?
  - The pattern I notice is _____ because _____.
  - I can use this pattern in an explanation by _____.
  - From the pattern _____ I predict that _____ because _____.

Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts; therefore, complex natural and designed structures/systems can be analyzed to determine how they function.
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.
  - How are the structures related to the functions in this scenario or investigation?
  - What structures are important in this scenario or investigation?
  - Describe a different structure that might be able to perform the same function?
  - The important structures are _____.
  - The _____ (structure) performs _____ (function).
  - I think that _____ (structure) could perform the same function because _____.

Systems and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
- Models are limited in that they only represent certain aspects of the system under study.
  - What are the parts of the system?
  - Describe how the parts of the system interact.
  - What are the interactions of the system?
  - How does the model represent the system?
  - The parts of the system are _____ , _____ , _____...
  - In this system _____ interacts with _____ to cause _____.
  - The model I used to describe the system we studied was ____ because it ___.

Energy and Matter

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

- Matter is conserved because atoms are conserved in physical and chemical processes.
- Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.
- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).
- The transfer of energy can be tracked as energy flows through a designed or natural system.
  - How do energy changes appear in this scenario or investigation?
  - Describe the cycles of matter represented in this scenario or investigation.
  - How do energy and matter interact in this scenario or investigation?
  - I think energy changed because _____.
  - Matter in this system went from _____ to _____.
  - The evidence I have for matter being conserved in this system is _____.
  - The interaction of energy and matter in this system is observed when _____.

Cause and Effect

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.
  - Does the effect have more than one cause?
  - What predictions are possible from the cause-effect relationship?
  - How have you used the cause-effect relationship in a scientific argument?
  - One cause of _____ (effect) might be _____.
  - From the cause-effect relationship, I would claim that _____.
  - I tested what I thought was the cause-effect relationship by _____ .

Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales, including the atomic scale.
- Small changes in one part of a system might cause large changes in another part.
- Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
- Systems in dynamic equilibrium are stable due to a balance of feedback mechanisms
  - How does the system display stability?
  - What changes were occurring while the system was stable?
  - Describe how the system is able to remain stable.
  - Where else have you seen this type of stability (or change)?
  - The system displays stability by _____.
  - Even though the system appears stable, I know that _____ (changes) were happening.
  - The reason this system can remain stable is _____.

Scale, Proportion, and Quantity

It is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change when considering phenomena.

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
- The observed function of natural and designed systems may change with scale.
- Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
- Scientific relationships can be represented through the use of algebraic expressions and equations.
- Phenomena that can be observed at one scale may not be observable at another scale.
  - How does proportion fit into this scenario or investigation?
  - How does scale fit into this scenario or investigation?
  - How does quantity fit into this scenario or investigation?
  - Is this phenomenon visible at other scales? Explain your thinking.
  - In this science idea, scale is important because _____.
  - In this science idea, proportion is important because _____.
  - In this science idea, quantity is important because _____.

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