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

GRADE LEVEL PROGRESSIONS

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Performance Expectation</th>
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<tbody>
<tr>
<td>K.S.1A.4</td>
<td>Analyze and interpret data from observations, measurements, or investigations to understand patterns and meanings.</td>
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<tr>
<td>1.S.1A.4</td>
<td>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.</td>
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<td>2.S.1A.4</td>
<td>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.</td>
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<tr>
<td>3.S.1A.4</td>
<td>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.</td>
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<tr>
<td>4.S.1A.4</td>
<td>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.</td>
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<tr>
<td>5.S.1A.4</td>
<td>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.</td>
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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:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>3</td>
<td>Students will need to identify variables</td>
</tr>
<tr>
<td>4</td>
<td>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.</td>
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<tr>
<td>5</td>
<td>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.</td>
</tr>
<tr>
<td>6</td>
<td>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. 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.</td>
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<tr>
<td>High School</td>
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- Be consistent on either axis.
  - 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).

**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.

- 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.

- 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.
- 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.
- 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.
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.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Subject</th>
<th>Example</th>
<th>Non-Example</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>Earth Science</td>
<td>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.</td>
<td>Students are given weather data and an explanation of the data.</td>
</tr>
<tr>
<td>4-5</td>
<td>Life Science</td>
<td>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.</td>
<td>Teacher will provide explanations concerning the data dealing with the stages of plant development.</td>
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<tr>
<td>8</td>
<td>Earth Science</td>
<td>The teacher provides students with sources of data (maps, information texts, USGS tables) on the location of volcanoes and earthquakes. Students</td>
<td>Teacher provides an interpretation of data concerning the distribution</td>
</tr>
<tr>
<td>High School Biology</td>
<td>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.</td>
<td>Teacher prescribed lab on inheritable traits to validate expected outcomes.</td>
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</tbody>
</table>