Grade Four
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student will be able to do when conducting activities and investigations and represents the student understanding of the nature of science. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 4.1 represent more specifically what a student should be able to do as a result of science experiences in fourth grade. Across the grade levels, the skills in the "Scientific Investigation, Reasoning, and Logic" strand form a nearly continuous sequence of investigative skills and an understanding of the nature of science. It is important that the classroom teacher understand how the skills in standard 4.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). The fourth-grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed.

4.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) distinctions are made among observations, conclusions, inferences, and predictions; b) objects or events are classified and arranged according to characteristics or properties; c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units; d) appropriate instruments are selected and used to measure elapsed time; e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources; f) independent and dependent variables are identified; g) constants in an experimental situation are identified; h) hypotheses are developed as cause and effect relationships; i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs; j) numerical data that are contradictory or unusual in experimental results are recognized; k) data are communicated with simple graphs, pictures, written statements, and numbers; l) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and m) current applications are used to reinforce science concepts.

Overview

The skills described in standard 4.1 are intended to define the "investigate" component of all of the other fourth-grade standards (4.2–4.9). The intent of standard 4.1 is that students will continue to develop a range of inquiry skills, achieve proficiency with those skills in the context of the concepts developed at the fourth-grade level, and strengthen their understanding of the nature of science. **Standard 4.1 does not require a discrete unit be taught on scientific investigation and the nature of science because the skills that make up the standard should be incorporated in all the other fourth-grade standards.** It is also intended that by developing these skills, students will achieve greater understanding of scientific inquiry and the nature of science as well as more fully grasp the content-related concepts.

4.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) distinctions are made among observations, conclusions, inferences, and predictions;
b) objects or events are classified and arranged according to characteristics or properties;
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Understanding the Standard
(Background Information for Instructor Use Only)

- The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts:
  a) the natural world is understandable;
  b) science is based on evidence, both observational and experimental;
  c) science is a blend of logic and innovation;
  d) scientific ideas are durable yet subject to change as new data are collected;
  e) science is a complex social endeavor; and
  f) scientists try to remain objective and engage in peer review to help avoid bias.

  In grade four, an emphasis should be placed on concepts a, b, c, d, and e.
- Science assumes that the natural world is understandable. Scientific inquiry can provide explanations about nature. This expands students' thinking from just a knowledge of facts to understanding how facts are relevant to everyday life.
- Science demands evidence. Scientists develop their ideas based on

Essential Knowledge, Skills, and Processes

In order to meet this standard, it is expected that students will

- differentiate among simple observations, conclusions, inferences, and predictions, and correctly apply the terminology in oral and written work.
- analyze a set of 20 or fewer objects or pictures. Sort them into categories to organize the data (qualitative or quantitative); and construct bar graphs and line graphs depicting the distribution of those data based on characteristics or properties.
- use millimeters, centimeters, meters, kilometers, grams, kilograms, milliliters, liters, and degrees Celsius in measurement.
- choose the appropriate instruments, including centimeter rulers, meter sticks, scales, balances, graduated cylinders, beakers, and Celsius thermometers, for making basic metric measures.
- measure elapsed time using a stopwatch or a clock.
- make predictions, inferences, and draw conclusions using a variety of sources such as picture graphs, bar graphs, and basic line graphs.

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Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way. • Science uses both logic and innovation. Innovation has always been an important part of science. Scientists draw upon their creativity to visualize how nature works, using analogies, metaphors, and mathematics. • Scientific ideas are durable yet subject to change as new data are collected. The main body of scientific knowledge is very stable and grows by being corrected slowly and having its boundaries extended gradually. Scientists themselves accept the notion that scientific knowledge is always open to improvement and can never be declared absolutely certain. New questions arise, new theories are proposed, new instruments are invented, and new techniques are developed. • Science is a complex social endeavor. It is a complex social process for producing knowledge about the natural world. Scientific knowledge represents the current consensus among scientists as to what is the best explanation for phenomena in the natural world. This consensus does not arise automatically, since scientists with different backgrounds from all over the world may interpret the same data differently. To build a	• analyze the variables in a simple experiment. Identify the independent variable and the dependent variable. Decide which other variable(s) must be held constant (not allowed to change) in order for the investigation to represent a fair test. • create a plausible hypothesis, stated in terms of cause (if) and effect (then), from a set of basic observations that can be tested. Hypotheses can be stated in terms such as: "If the water temperature is increased, then the amount of sugar that can be dissolved in it will increase." • organize and analyze data from a simple experiment. Construct bar graphs and line graphs depicting the data. • judge which, if any, data in a simple set of results (generally 10 or fewer in number) appear to be contradictory or unusual. • present results of a simple experiment using graphs, pictures, statements, and numbers. • construct a physical model to clarify an explanation, demonstrate a relationship, or solve a need.

4.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) distinctions are made among observations, conclusions, inferences, and predictions; b) objects or events are classified and arranged according to characteristics or properties; c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units; d) appropriate instruments are selected and used to measure elapsed time; e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources; f) independent and dependent variables are identified; g) constants in an experimental situation are identified; h) hypotheses are developed as cause and effect relationships; i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs; j) numerical data that are contradictory or unusual in experimental results are recognized; k) data are communicated with simple graphs, pictures, written statements, and numbers; l) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and m) current applications are used to reinforce science concepts.

Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
consensus, scientists communicate their findings to other scientists and attempt to replicate one another’s findings. In order to model the work of professional scientists, it is essential for fourth-grade students to engage in frequent discussions with peers about their understanding of their investigations. • An observation is what you see, feel, taste, hear, or smell. Scientists construct knowledge from observations and inferences, not observations alone. To communicate an observation accurately, one must provide a clear description of exactly what is observed and nothing more. Those conducting investigations need to understand the difference between what is seen and what inferences, conclusions, or interpretations can be drawn from the observation. • An inference is a tentative explanation based on background knowledge and available data. • A scientific prediction tells what may happen in some future situation. It is based on the application of scientific principles and factual information. • Accurate observations and evidence are necessary to draw realistic and plausible conclusions. A conclusion is a summary statement based on the	

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Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
results of an investigation. • Conclusions are drawn by making judgments after considering all the information you have gathered. Conclusions are based on details and facts. • Systematic investigations require standard measures (metric), consistent and reliable tools, and organized reporting of data. The way the data are displayed can make it easier to uncover important information. This can assist in making reliable scientific forecasts of future events. • Elapsed time is the amount of time that has passed between two given times. (*See Grade Four Mathematics Curriculum Framework, Standard 4.9, page 24.*) • An experiment is a fair test driven by a hypothesis. A fair test is one in which only one variable is compared. • A hypothesis is a prediction about the relationship between variables. A hypothesis is an educated guess/prediction about what will happen based on what you already know and what you have already learned from your research. It must be worded so that it is "testable."	

4.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) distinctions are made among observations, conclusions, inferences, and predictions; b) objects or events are classified and arranged according to characteristics or properties; c) appropriate instruments are selected and used to measure length, mass, volume, and temperature in metric units; d) appropriate instruments are selected and used to measure elapsed time; e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources; f) independent and dependent variables are identified; g) constants in an experimental situation are identified; h) hypotheses are developed as cause and effect relationships; i) data are collected, recorded, analyzed, and displayed using bar and basic line graphs; j) numerical data that are contradictory or unusual in experimental results are recognized; k) data are communicated with simple graphs, pictures, written statements, and numbers; l) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and m) current applications are used to reinforce science concepts.

Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
• In order to conduct an experiment, one must recognize all of the potential variables or changes that can affect its outcome. • An independent variable is the factor in an experiment that is altered by the experimenter. The independent variable is purposely changed or manipulated. • A dependent variable is the factor in an experiment that changes as a result of the manipulation of the independent variable. • The constants in an experiment are those things that are purposefully not changed and remain the same throughout the experiment. • In science, it is important that experiments and the observations recorded are repeatable. There are two different types of data – qualitative and quantitative. Qualitative data deal with descriptions and data that can be observed, but not measured. Quantitative data are data that can be counted or measured and the results can be recorded using numbers. Quantitative data can be represented visually in graphs and charts. Quantitative data define whereas qualitative data describe. Quantitative data are more valuable in science because they allow direct comparisons between observations made by different people or at different times.	

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d) appropriate instruments are selected and used to measure elapsed time;
e) predictions and inferences are made, and conclusions are drawn based on data from a variety of sources;
f) independent and dependent variables are identified;
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Understanding the Standard

(Background Information for Instructor Use Only)

Example of Qualitative vs. Quantitative Data

Main Street Elementary School Science Club

Qualitative	**Quantitative**
• Friendly • Like science • Positive about school	• 10 fourth-grade students and 12 fifth-grade students • 14 girls, 8 boys • 92 percent participated in the divisionwide science fair last year

- It is important for students to apply the science content they have learned to current events and applications.

Essential Knowledge, Skills, and Processes

Grade Five
Science Strand

Scientific Investigation, Reasoning, and Logic

This strand represents a set of systematic inquiry skills that defines what a student will be able to do when conducting activities and investigations, and represents the student understanding of the nature of science. The various skill categories are described in the "Investigate and Understand" section of the Introduction to the *Science Standards of Learning*, and the skills in science standard 5.1 represent more specifically what a student should be able to do as a result of science experiences in fifth grade. Across the grade levels, the skills in the "Scientific Investigation, Reasoning, and Logic" strand form a nearly continuous sequence of investigative skills and an understanding of the nature of science. It is important that the classroom teacher understand how the skills in standard 5.1 are a key part of this sequence (i.e., K.1, K.2, 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1). The fifth-grade curriculum should ensure that skills from preceding grades are continuously reinforced and developed.

5.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) items such as rocks, minerals, and organisms are identified using various classification keys; b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools; c) estimates are made and accurate measurements of elapsed time are made using proper tools; d) hypotheses are formed from testable questions; e) independent and dependent variables are identified; f) constants in an experimental situation are identified; g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements; h) predictions are made using patterns from data collected, and simple graphical data are generated; i) inferences are made and conclusions are drawn; j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and k) current applications are used to reinforce science concepts.

Overview

The skills in standard 5.1 are intended to define the “investigate” component and the understanding of the nature of science for all of the other fifth-grade standards (5.2–5.7). The intent of standard 5.1 is for students to continue to develop a range of inquiry skills, achieve proficiency with those skills, and develop and reinforce their understanding of the nature of science in the context of the concepts developed at the fifth-grade level. **Standard 5.1 does not require a discrete unit be taught on scientific investigation because the skills that make up the standard should be incorporated in all the other fifth-grade standards.** It is also intended that by developing these skills, students will achieve a greater understanding of scientific inquiry and the nature of science and will more fully grasp the content-related concepts.

5.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which a) items such as rocks, minerals, and organisms are identified using various classification keys; b) estimates are made and accurate measurements of length, mass, volume, and temperature are made in metric units using proper tools; c) estimates are made and accurate measurements of elapsed time are made using proper tools; d) hypotheses are formed from testable questions; e) independent and dependent variables are identified; f) constants in an experimental situation are identified; g) data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements; h) predictions are made using patterns from data collected, and simple graphical data are generated; i) inferences are made and conclusions are drawn; j) models are constructed to clarify explanations, demonstrate relationships, and solve needs; and k) current applications are used to reinforce science concepts.

Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
• The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts: a) the natural world is understandable; b) science is based on evidence, both observational and experimental; c) science is a blend of logic and innovation; d) scientific ideas are durable yet subject to change as new data are collected; e) science is a complex social endeavor; and f) scientists try to remain objective and engage in peer review to help avoid bias. In grade five, an emphasis should be placed on concepts a, b, c, d, and e. • Science assumes that the natural world is understandable. Scientific inquiry can provide explanations about nature. This expands students' thinking from just a knowledge of facts to understanding how facts are relevant to everyday life. • Science demands evidence. Scientists develop their ideas based on evidence and they change their ideas when new evidence becomes available or the old evidence is viewed in a different way.	In order to meet this standard, it is expected that students will • use classification keys to identify rocks, minerals, and organisms. • select and use the appropriate instruments, including centimeter rulers, meter sticks, graduated cylinders, balances, stopwatches, and thermometers for making basic measurements. • make reasonable estimations of length, mass, volume, and elapsed time. • measure length, mass, volume, and temperature using metric measures. This includes millimeters, centimeters, meters, kilometers, grams, kilograms, milliliters, liters, and degrees Celsius. • use a testable question to form a hypothesis as cause and effect (e.g., "if…, then…") statement. • analyze the variables in a simple experiment and identify the independent and dependent variables, and the constants. • collect, record, analyze, and report data, using charts and tables, and translate numerical data into bar or line graphs. • make predictions based on trends in data. This requires the recognition

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Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
• Science uses both logic and innovation. Innovation has always been an important part of science. Scientists draw upon their creativity to visualize how nature works, using analogies, metaphors, and mathematics. • Scientific ideas are durable yet subject to change as new data are collected. The main body of scientific knowledge is very stable and grows by being corrected slowly and having its boundaries extended gradually. Scientists themselves accept the notion that scientific knowledge is always open to improvement and can never be declared absolutely certain. New questions arise, new theories are proposed, new instruments are invented, and new techniques are developed. • Science is a complex social endeavor. It is a complex social process for producing knowledge about the natural world. Scientific knowledge represents the current consensus among scientists as to what is the best explanation for phenomena in the natural world. This consensus does not arise automatically, since scientists with different backgrounds from all over the world may interpret the same data differently. To build a consensus, scientists communicate their findings to other scientists and attempt to replicate one another's findings. In order to model the work of professional scientists, it is essential for fifth-grade students to engage in frequent discussions with peers about their understanding of	of patterns and trends and determination of what those trends may represent. • make inferences and draw conclusions. • distinguish between inferences and conclusions. • construct a physical model to clarify an explanation, demonstrate a relationship, or solve a need.

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Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
their investigations. • Systematic investigations require standard measures and consistent and reliable tools. Metric measures are a standard way to make measurements and are recognized around the world. • A classification key is an important tool used to help identify objects and organisms. It consists of a branching set of choices organized in levels, with most levels of the key having two choices. Each level provides more specific descriptors, eventually leading to identification. • A hypothesis is an educated guess/prediction about what will happen based on what you already know and what you have already learned from your research. It must be worded so that it is "testable." The hypothesis can be written as an "If…, then…." statement, such as "If all light is blocked from a plant for two weeks, then the plant will die." • An independent variable is the factor in an experiment that is altered by the experimenter. The independent variable is purposely changed or manipulated. • A dependent variable is the factor in an experiment that changes as a result of the manipulation of the independent variable. • The constants in an experiment are those things that are purposefully	

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Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
kept the same throughout the experiment. • When conducting experiments, data are collected, recorded, analyzed, and communicated using proper graphical representations and metric measurements. • Systematic investigations require organized reporting of data. The way the data are displayed can make it easier to see important patterns, trends, and relationships. Bar graphs and line graphs are useful tools for reporting discrete data and continuous data, respectively. • A scientific prediction is a forecast about what may happen in some future situation. It is based on the application of factual information and principles and recognition of trends and patterns. • Estimation is a useful tool for making approximate measures and giving general descriptions. In order to make reliable estimates, one must have experience using the particular unit. • An inference is a tentative explanation based on background knowledge and available data. • A conclusion is a summary statement based on the results of an investigation. Scientific conclusions are based on verifiable observations (science is empirical).	

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Understanding the Standard (Background Information for Instructor Use Only)	**Essential Knowledge, Skills, and Processes**
• Scientific modeling is the process of generating abstract, conceptual, graphical and/or mathematical models. It is an approximation or simulation of a real system that omits all but the most essential variables of the system. In order to create a model, a scientist must first make some assumptions about the essential structure and relationships of objects and/or events in the real world. These assumptions are about what is necessary or important to explain the phenomena. • It is important for students to apply the science content that they have learned to current issues and applications.	