Introduction to the performance standards for Science

There are two widely used and respected national documents in science which we have taken into account: the National Research Council (NRC) National Science Education Standards (1996) and the American Association for the Advancement of Science (AAAS) Project 2061 Benchmarks for Science Literacy (1993). We found the AAAS analysis of the Benchmarks and the NRC Draft to be helpful in seeing the substantial degree of agreement between the two documents. We also consulted New Standards partner statements about standards and international documents, including the work of the Third International Mathematics and Science Study and the Organisation for Economic Co-operation and Development. Many of these sources, like the Benchmarks, give greater emphasis to technology and the applications of science than does the NRC.

The framework for the Science performance standards reflects New Standards partner representatives’ distillation of these several sources of guidance:

1. Physical Sciences Concepts;
2. Life Sciences Concepts;
3. Earth and Space Sciences Concepts;
4. Scientific Connections and Applications;
5. Scientific Thinking;
6. Scientific Tools and Technologies;
7. Scientific Communication;

As the amount of scientific knowledge explodes, the need for students to have deep understanding of fundamental concepts and ideas upon which to build increases; as technology makes information readily available, the need to memorize vocabulary and formulas decreases. There is general agreement among the science education community, in principle, that studying fewer things more deeply is the direction we would like to go. The choices about what to leave out and what to keep are hotly debated. There are 855 benchmarks and the content standards section of the NRC standards runs nearly 200 pages, so there are still choices to be made in crafting a reasonable set of performance standards.

When the goal is deep understanding, it is necessary to revisit concepts over time. Students show progressively deeper understanding as they use the concept in a range of familiar situations to explain observations and make predictions, then use the concept in unfamiliar situations; as they represent the concept in multiple ways (through words, diagrams, graphs, or charts), and explain the concept to another person. The conceptual understanding standards make explicit that students should be able to demonstrate understanding of a scientific concept “by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate).” Both aspects of understanding—explaining and representing—are required to meet these standards.

For most people and most concepts, there is a progression from phenomenological to empirical to theoretical, or from a qualitative to a quantitative understanding. We have chosen one important concept, density, to illustrate the progression. To do this we use “Flinkers” at the elementary school level (see page 136), “Discovering Density” at the middle school level (see Volume 2, page 101), and “The Density of Sand” at the high school level (see Volume 3, page 84). The expectation for any particular concept at any particular level can only be described with a satisfactory degree of precision and accuracy in the degree of detail adopted by AAAS and NRC; we strongly urge users of these performance standards to consult either or both of those documents for guidance on other concepts.

Establishing separate standards for these areas is a mechanism for highlighting the importance of these areas, but does not imply that they are independent of conceptual understanding. The NRC standards, by declaring that inquiry is not only a teaching method but also an object of study, should put the time-worn “content versus process” debate to rest, and focus effort on combining traditionally defined content with process. As the work samples that follow illustrate, good work usually provides evidence of both.
Resources

Reviewers of drafts of these performance standards have pointed out that our expectations are more demanding, both in terms of student time and access to resources, than they consider reasonable for all students. We acknowledge the distance between our goals and the status quo, and the fact that there is a tremendous disparity in opportunities between the most and least advantaged students. We think that there are at least two strategies that must be pursued to achieve our goals—making better use of existing, out-of-school resources and making explicit the connection between particular resources and particular standards.

Best practice in science has always included extensive inquiry and investigation, but it is frequently given less emphasis in the face of competing demands for student time and teacher resources. An elementary teacher faced with the unfamiliar territory of project work in science or a secondary teacher faced with the prospect of guiding 180 projects and investigations can legitimately throw up his or her hands and cry, “Help!” Youth and community-based organizations, such as the Boy Scouts of America, Girl Scouts of the U.S.A., and 4-H, have science education on their agenda. Thus, we have incorporated examples of projects and investigations that are done outside of school to make clear that help is available.

We acknowledge that some of the performance descriptions and examples presuppose resources that are not currently available to all students, even those who take advantage of the out-of-school opportunities available to them. Yet, New Standards partners have adopted a Social Compact, which says, in part, “Specifically, we pledge to do everything in our power to ensure all students a fair shot at reaching the new performance standards…This means that they will be taught a curriculum that will prepare them for the assessments, that their teachers will have the preparation to enable them to teach it well, and there will be an equitable distribution of the resources the students and their teachers need to succeed.”

All of the district, state, and national documents in science make explicit the need for students to have hands-on experience and to use information tools. Thus, for example, Science, Technology and Engineering, makes explicit reference to using telecommunications to acquire and share information. A recent National Center for Education Statistics survey recently reported that only 50% of schools and fewer than 9% of instructional rooms currently have access to the Internet. We know that this is an equity issue—that far more than 9% of the homes in the United States have access to the Internet and that schools must make sure that students’ access to information and ideas does not depend on what they get at home—so we have crafted performance standards that would use the Internet so that people will make sure that all students have access to it. Since the New Standards...
**S1 Physical Sciences Concepts**

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

The student produces evidence that demonstrates understanding of:

**S1 a** Properties of objects and materials, such as similarities and differences in the size, weight, and color of objects; the ability of materials to react with other substances; and different states of materials.

**S1 b** Position and motion of objects, such as how the motion of an object can be described by tracing and measuring its position over time; and how sound is produced by vibrating objects.

**S1 c** Light, heat, electricity, and magnetism, such as the variation of heat and temperature; how light travels in a straight line until it strikes an object or how electrical circuits work.

Examples of activities through which students might demonstrate conceptual understanding of physical sciences include:

- Investigate the browning process of apple slices and the factors that slow or speed up the process. 1a
- Use physical properties such as color, texture, or hardness to sort objects into two or more categories; change the categories to include a new object; and explain the rule to another student. 1a, 4a
- Use diagrams to explain the characteristics of ice melting, water boiling, and steam condensing; and illustrate how these kinds of characteristics can affect environments and the organisms that live in them. 1a, 2a, 2b, 2t
- Predict the bouncing pattern of a basketball under different throwing conditions using previous observations of force and motion. 1b
- Make a musical instrument, explain the relationship between sound and shape, and compare this to a structure/function relationship in an organism. 1b, 2a
- Investigate heat and friction by burning, rubbing, or mixing substances together; explain similarities and differences. 1c
- Use knowledge of magnetism to predict what materials will be attracted, repelled, or unaffected by a magnet, then conduct an experiment to confirm or reject their predictions. 1c, 3a

**S2 Life Sciences Concepts**

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

The student produces evidence that demonstrates understanding of:

**S2 a** Characteristics of organisms, such as survival and environmental support; the relationship between structure and function; and variations in behavior.

**S2 b** Life cycles of organisms, such as how inheritance and environment determine the characteristics of an organism; and that all plants and animals have life cycles.

**S2 c** Organisms and environments, such as the interdependence of animals and plants in an ecosystem; and populations and their effects on the environment.

**S2 d** Change over time, such as evolution and fossil evidence depicting the great diversity of organisms developed over geologic history.

Examples of activities through which students might demonstrate conceptual understanding of life sciences include:

- Predict how long a plant will live planted in a closed glass jar located by a window; and explain what additional information regarding the plant and the surrounding environment would be needed to improve the prediction. 2a, 1a, 3a, 3b
- Complete a 4-H animal care project; write a report explaining the growth and development of the animal and present the animal at the county-wide fair. 2a, 2b, 2t, 7a, 8b
- Make drawings of observations showing the life cycle of a plant or animal. 2b
- Explain the differences between inherited and environmental features of individuals such as flower colors or bike riding ability and describe the physical characteristics of the environment that could affect these features. 2a, 2b, 2t, 2d, 1a, 4a
- Plan the supplies and equipment needed for a camping trip and explain their purposes. 2a, 2b, 2c, 2d, 1a, 4a, 4b
- Explain how organisms, both human and other, cause changes in their environments and how some of these changes can be detrimental to other organisms. 2a, 2b, 2c, 2d, 1a, 4a, 4b
- Use more than one medium such as models, text, drawings, or oral explanations to show how various organisms have changed over time to fill a variety of niches. 2t, 2d, 4a
- Describe the similarities and differences between fossils and related contemporary organisms and explain how environmental factors contributed to these similarities and differences. 2a, 2b, 2d, 1a, 3a, 3c, 4a
Earth and Space Sciences Concepts

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

The student produces evidence that demonstrates understanding of:
- **S3 a** Properties of Earth materials, such as water and gases; and the properties of rocks and soils, such as texture, color, and ability to retain water.
- **S3 b** Objects in the sky, such as Sun, Moon, planets, and other objects that can be observed and described; and the importance of the Sun to provide the light and heat necessary for survival.
- **S3 c** Changes in Earth and sky, such as changes caused by weathering, volcanism, and earthquakes; and the patterns of movement of objects in the sky.

Examples of activities through which students might demonstrate conceptual understanding of Earth and space sciences include:
- Investigate how the properties of soil can affect the growth of a plant. 3a, 1a, 2a, 2b, 2c, 4a
- Predict what kinds of materials would be useful for different purposes, such as in buildings or as sources of fuel, because of their physical and chemical properties. 3a, 1a
- Observe and keep a record of the shape of the Moon for several months; and then make drawings predicting what will happen during the next week. 3b, 3c
- Make observations of the changes in an object’s shadow during the course of a day and investigate the source of the variation. 3b, 3c
- Write a story that describes what happens to a drop of water and the physical environment through which it flows as it travels from a lake to a river via the Earth’s atmosphere. 3a, 3b, 1a, 4a
- Collect information from a weather station and use the information to explain the patterns of change from fall to winter in terms of weather and the position and movement of objects in the sky. 3b, 3c, 4a, M1a, M1c, M1f, A1a

Scientific Connections and Applications

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

The student produces evidence that demonstrates understanding of:
- **S4 a** Big ideas and unifying concepts, such as order and organization; models, form and function; change and constancy; and cause and effect.
- **S4 b** The designed world, such as development of agricultural techniques; and the viability of technological designs.
- **S4 c** Personal health, such as nutrition, substance abuse, and exercise; germs and toxic substances; personal and environmental safety.
- **S4 d** Science as a human endeavor, such as communication, cooperation, and diverse input in scientific research; and the importance of reason, intellectual honesty, and skepticism.

Examples of activities through which students might demonstrate conceptual understanding of scientific connections and applications include:
- Conduct an experiment to determine which brand of paper towel is the best in terms of form and function, cause and effect, cost and personal preference, and write an advertisement for the brand highlighting findings of the experiment. 4a, 4b, 1a, 3a
- Earn the Webelos Engineer Badge (Boy Scouts of America) or the Brownie Building Art Try-It (Girl Scouts of the U.S.A.) and explain the design of the model. 4b, 4d, 1a, 1b, 1c
- Explain why people should wash their hands when preparing food. 4a, 3c
- Make recommendations to improve the selection of food in the school vending machines so that students can make healthier choices. 4c, 2b, M8a, A1b
- Build a solar cooker and explain what foods can or cannot be cooked safely within the temperature range achieved. 4b, 4c, 2a
- Interview a person who has a job that interests you and write a report explaining how studying science helped the person prepare for the job. 4d
**S5 Scientific Thinking**

The student demonstrates scientific inquiry and problem solving by using thoughtful questioning and reasoning strategies, common sense and conceptual understanding from Science Standards 1 to 4, and appropriate methods to investigate the natural world; that is, the student:

- **S5 a** Asks questions about natural phenomena; objects and organisms; and events and discoveries.
- **S5 b** Uses concepts from Science Standards 1 to 4 to explain a variety of observations and phenomena.
- **S5 c** Uses evidence from reliable sources to construct explanations.
- **S5 d** Evaluates different points of view using relevant experiences, observations, and knowledge; and distinguishes between fact and opinion.
- **S5 e** Identifies problems; proposes and implements solutions; and evaluates the accuracy, design, and outcomes of investigations.
- **S5 f** Works individually and in teams to collect and share information and ideas.

**Examples of activities through which students might demonstrate scientific thinking include:**

- Evaluate the claims of a new product: describe the questions and evidence required to substantiate the claims; conduct an investigation to test ideas; and evaluate the accuracy of the conclusions. 5a, 5b, 5c, 5e
- Work with others to examine the changes in the flora, fauna, and environment in a one square meter plot, caused by recent construction, explain the observations, and make predictions about the future of this microsystem. 5a, 5b, 5c, 5d, 5f, 2a, 2b, 2c
- Use data from one investigation to generate a prediction and conduct a new investigation. 5a, 5b, 5c, 5e
- Summarize a series of newspaper and magazine articles on a current topic, e.g., El Niño; use multiple sources to evaluate accuracy in the articles; and write a revised article putting all the relevant ideas together. 5a, 5b, 5c, 5d, 3a

**S6 Scientific Tools and Technologies**

The student demonstrates competence with the tools and technologies of science by using them to collect data, make observations, analyze results, and accomplish tasks effectively; that is, the student:

- **S6 a** Use technology and tools (such as rulers, computers, balances, thermometers, watches, magnifiers, and microscopes) to gather data and extend the senses.
- **S6 b** Collects and analyzes data using concepts and techniques in Mathematics Standard 4, such as average, data displays, graphing, variability, and sampling.
- **S6 c** Acquires information from multiple sources, such as experimentation and print and non-print sources.

**Examples of activities through which students might demonstrate competence with the tools and technologies of science include:**

- Collect information from the United States Geological Survey and use the information to identify trends in geologic movement in your hometown or state. 6c, 3a, 3b, 3c
- Conduct a survey of students’ electricity and gas use at home, compare the data to that of other students, and select an appropriate way to display the comparative data. 6b, 2c, 4b
- Use telecommunications to compare data on similar investigations with students in another school. 6c
- Use electronic data bases to find out about the nutritional value of food available in the cafeteria and compare with alternative selections or snack foods. 6b, 4c

To see how these performance descriptions compare with the expectations for middle school and high school, turn to pages 232-239.

The Science standards are founded upon both the National Research Council’s National Science Education Standards and the American Association for the Advancement of Science’s Project 2061 Benchmarks for Science Literacy. These documents, each of which runs to several hundred pages, contain detail that amplifies the meaning of the terms used in the performance descriptions.
**S7 Scientific Communication**

The student demonstrates effective scientific communication by clearly describing aspects of the natural world using accurate data, graphs, or other appropriate media to convey depth of conceptual understanding in science; that is, the student:

- **S7 a** Represents data and results in multiple ways, such as numbers, tables, and graphs; drawings, diagrams, and artwork; and technical and creative writing.
- **S7 b** Uses facts to support conclusions.
- **S7 c** Communicates in a form suited to the purpose and the audience, such as writing instructions that others can follow.
- **S7 d** Critiques written and oral explanations, and uses data to resolve disagreements.

**Examples of activities through which students might demonstrate competence in scientific communication include:**

- Write and illustrate a creative story to explain the food chain to a younger brother or sister. 7a, 7c, 2c
- Make a poster of charts and graphs to communicate effective nutrition and health habits. 7a, 2a, 4b
- Work with other students to create a skit depicting the sequence of events and the characters in an important scientific discovery. 7c, 4d
- Prepare a report, with graphs, charts, and diagrams, on the optimal number and placement of recycling containers, based on trash disposal data from the classroom and the entire school. 7a, 4b, 6b, M7, A1b

**S8 Scientific Investigation**

The student demonstrates scientific competence by completing projects drawn from the following kinds of investigations, including at least one full investigation each year and, over the course of elementary school, investigations that integrate several aspects of Science Standards 1 to 7 and represent all four of the kinds of investigation:

- **S8 a** An experiment, such as conducting a fair test.
- **S8 b** A systematic observation, such as a field study.
- **S8 c** A design, such as building a model or scientific apparatus.
- **S8 d** Non-experimental research using print and electronic information, such as journals, video, or computers.

A single project may draw on more than one kind of investigation. A full investigation includes:

- Questions that can be studied using the resources available.
- Procedures that are safe, humane, and ethical; and that respect privacy and property rights.
- Data that have been collected and recorded (see also Science Standard 6) in ways that others can verify and analyze using skills expected at this grade level (see also Mathematics Standard 4).
- Data and results that have been represented (see also Science Standard 7) in ways that fit the context.
- Recommendations, decisions, and conclusions based on evidence.
- Acknowledgment of references and contributions of others.
- Results that are communicated appropriately to audiences.
- Reflection and defense of conclusions and recommendations from other sources and peer review.

**Examples of projects through which students might demonstrate competence in scientific investigation include:**

- Design, make, and fly kites; modifying the kites so they fly higher, maneuver more easily, or achieve some other goal. 8a, 8c
- Investigate why different plants live in the cracks of the sidewalk in different areas around the school. 8b, 2a
- Design and build a Rube Goldberg device and explain how changing aspects of the design made it work better. 8c, 4b
- Research a particular disease; compare local with national risk factors; and produce an information pamphlet that communicates the characteristics and risk associated with the disease. 8d, 4c
- Make a series of drawings and explain the seasonal succession of plants in a field near the school. 8d, 2b
- With a partner, select an endangered plant or animal in your area; collect information from reference books, magazines, video; debate whether the plant or animal should be saved or allowed to disappear, and why. 8d, 2c, 6c

Samples of student work that illustrate standard-setting performances for these standards can be found on pages 136-158.

The examples that follow the performance descriptions for each standard are examples of the work students might do to demonstrate their achievement. The examples also indicate the nature and complexity of activities that are appropriate to expect of students at the elementary level.

The cross-references that follow the examples highlight examples for which the same activity, and possibly even the same piece of work, may enable students to demonstrate their achievement in relation to more than one standard. In some cases, the cross-references highlight examples of activities through which students might demonstrate their achievement in relation to standards for more than one subject matter.
Work Sample & Commentary: Flinkers

The task

Students were instructed to complete a laboratory activity in which they adjusted the mass and/or the volume of an object so that the object would not float on top of water or sink...it would “flink.”

The task calls for the student to explore the range of available floating and sinking objects. In order to accomplish the task, it is necessary to combine floating and sinking objects to construct one of the correct density.

Circumstances of performance

This sample of student work was produced under the following conditions:

- alone
- in class
- with teacher feedback
- timed
- in a group
- as homework
- with peer feedback
- opportunity for revision

What the work shows

A Physical Sciences Concepts: The student produces evidence that demonstrates understanding of properties of objects and materials, such as similarities and differences in the size, weight, and color of objects...

The drawings provide evidence of sorting objects by observable properties and representing the findings.

A The students sorted common objects into those that floated and those that sank and recorded their findings.

B They used trial and error to find combinations that were neutrally buoyant (that “flinked”) and drew the results.

The written summary provides evidence of conceptual understanding of density, an observable and measurable property of objects and materials.

C The statement, “To make something flink, the mass and volume had to equal one,” is acceptable for the elementary school level. At the middle school level, one would expect the student to discuss density in terms of a ratio; for example, “To make something flink, the ratio of the mass and the volume had to equal one,” or “To make something flink, the mass divided by the volume had to equal one.” Further, and although this is perhaps taken for granted, an adequate middle school response would make explicit the density of water, which equals one.

D Additional evidence of understanding the concept of density is provided in this sentence which...
says that the addition of mass changes the buoyancy of the object.

E The final sentence completes the summary with reference to observable properties.

This work is an unrevised piece of homework. There are three spelling errors (“process,” “absorbe,” and “determination”) and a missing apostrophe.
Work Sample & Commentary: The Growing Tree

The task
A small tree is planted in a meadow. After 20 years it has grown into a big tree, weighing 250 kg more than when it was planted. Where do the extra 250 kg come from? Explain your answer as fully as you can.

Circumstances of performance
These samples of student work were produced under the following conditions:

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The task was part of a state assessment program and unrelated to the curriculum that the students were studying.

What the work shows
S2 a  Life Sciences Concepts: The student produces evidence that demonstrates understanding of characteristics of organisms, such as survival and environmental support....

These samples effectively explain and represent the key components of photosynthesis at an appropriate level using simple text.

Sample 1
A Most of the components of photosynthesis are mentioned in the text: energy from the sun, carbon dioxide from the air, and water from the soil; though minerals are omitted.
B The drawing elaborates the text.

C This statement shows an understanding of the comparable ways that plants and animals grow. A more refined understanding would include the mechanism of adding cells, which is not mentioned in this work, and clarify the differences between plant and animal growth, i.e., that plants can and do make their own food while animals cannot. On the latter point, the idea that plants “eat” sugar is a common statement at the elementary level. The significance of the statement depends on what is meant by “eat.” If, for example, the student means “take into their cells and use for growth and other life processes,” this would be an accurate understanding.

D By recognizing that the plant makes sugar, this statement shows a high level of conceptualization for an elementary student.

These work samples illustrate standard-setting performances for the following parts of the standards:

S2 a  Life Sciences Concepts: Characteristics of organisms.
S7 a  Scientific Communication: Represent data and results in multiple ways.
**Scientific Communication:** The student represents data and results in multiple ways, such as...drawings, diagrams, and artwork.... Sample 1 was produced by a student in a special education reading program. Despite the punctuation, capitalization, and spelling errors, this sample effectively uses drawing to strengthen the written response.

**Sample 2**

E This work also includes three of the four major ingredients of photosynthesis—minerals, water, and light. Mentioning the fourth ingredient and the necessity for the presence of chlorophyll would be required in a middle school response. (See also the high school work sample entitled “Photosynthesis” in Volume 3 of these Performance Standards.)

F The elaboration, that the food is used to make cells and that the plant is made up of cells, shows progress from the elementary level, anticipating the middle school level, where structure and function are more extensively explored.

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Work Sample & Commentary: Inside the Rain Forest

The task
Students in a self-contained class participated in two units of study including poetry and nonfiction. During the poetry unit, they read and analyzed a wide variety of poems and learned how to write poetry. The nonfiction unit was focused on producing informational writing.

Two students asked if they could combine the informational writing assignment with their poetry using a topic that interested them. The product of that assignment was a book of poems on the rain forest which is excerpted here.

Circumstances of performance
This sample of student work was produced under the following conditions:

- alone
- in a group
- in class
- as homework
- with teacher feedback
- with peer feedback
- timed
- opportunity for revision

What the work shows

S2 a Life Sciences Concepts: The student produces evidence that demonstrates understanding of characteristics of organisms, such as survival and environmental support; the relationship between structure and function....

A B Each specific first person (“I” and “My”) statement identifies characteristics of a specific organism.

C The importance of bright colors for flower reproduction is evidence of understanding of form and function.

This work sample illustrates a standard-setting performance for the following parts of the standards:

S2 a Life Sciences Concepts: Characteristics of organisms.
S2 e Life Sciences Concepts: Organisms and environments.
S4 a Scientific Connections and Applications: Big ideas and unifying concepts.
Inside the Rain Forest

**Life Sciences Concepts:** The student produces evidence of understanding organisms and environments, such as the interdependence of animals and plants in an ecosystem.

D This statement correctly illustrates the dependent relationships between and among the tank, the insects, and the bromeliad.

**Scientific Connections and Applications:** The student produces evidence that demonstrates understanding of big ideas and unifying concepts, such as...form and function....

E The reference to the roots strangling a host tree illustrates understanding of the connection between form and function. This is also evident in a number of places in the remainder of the work.
Work Sample & Commentary: Drop of Water

The task
Students who had been studying weather were asked to write a story about a drop of water that goes through the water cycle.

Circumstances of performance
This sample of student work was produced under the following conditions:

- alone
- in class
- with teacher feedback
- timed
- in a group
- as homework
- with peer feedback
- opportunity for revision

What the work shows
In an engaging story, this work sample shows conceptual understanding for parts of three standards.

S3 b Earth and Space Sciences Concepts: The student produces evidence that demonstrates understanding of objects in the sky, such as...the importance of the Sun to provide the light and heat necessary for survival.
A The story begins with the important role of the sun.

S1 a Physical Sciences Concepts: The student produces evidence that demonstrates understanding of properties of objects and materials, such as...different states of materials.
B Conceptual understanding of different states of matter is demonstrated in the consistent and accurate relationships among phase, temperature, and volume, particularly the recognition that gases rise, and in the descriptions of how it feels to be a gas (“getting bigger”), to be a solid (“smaller”), and to condense from gas to liquid (“getting really crowded”).

This work sample illustrates a standard-setting performance for the following parts of the standards:

S1 a Physical Sciences Concepts: Properties of objects and materials.
S3 a Earth and Space Sciences Concepts: Properties of Earth materials.
S3 b Earth and Space Sciences Concepts: Objects in the sky.
S4 a Scientific Connections and Applications: Big ideas and unifying concepts.
Earth and Space Sciences Concepts: The student produces evidence that demonstrates understanding of properties of Earth materials, such as water and gases....

C. The role of dust as something upon which water can condense is evidence of understanding the water cycle.

D. The arrival in the Mississippi River, not in the original lake in Nebraska, shows further understanding of the water cycle.

Scientific Connections and Applications: The student produces evidence that demonstrates understanding of big ideas and unifying concepts, such as...change and constancy....

E. The final sentences, especially the conclusion, “The End...not really,” go beyond an understanding of the water cycle to suggest understanding of a unifying concept, change and constancy.

The response is distinguished by the representation of an abstract concept with clarity (i.e., molecular spacing and movement of water through the water cycle). The discussion of evaporation and condensation provide a more powerful explanation of the water cycle and demonstrates thorough understanding.
Work Sample & Commentary: Erosion

The task
An elementary class was involved in a year-long, interdisciplinary study of their state. On a field trip to a conservation center, they learned about wind and water erosion. When they returned, they wanted to learn more about erosion and which combinations of soil and grass were most effective in preventing erosion.

Circumstances of performance
This sample of student work was produced under the following conditions:

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</tr>
<tr>
<td>timed</td>
<td>opportunity for revision</td>
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What the work shows
The first page explains that this group of students examined Tall Fescue grass. Other groups in their class studied Perennial Rye, Crested Wheat, and Irrigated Pasture Mix (a mixture of these three and two other types). The second, third, and fourth pages explain the question, hypothesis, and procedures. The fifth page shows the plan for studying soils; the sixth, seventh, and eighth pages show the observations from the three soil types. The results of the soils’ analysis (without grass) are summarized on page 9. The next three pages (10-12) show the results of the same procedure for the same soils planted with Tall Fescue. The final page (13) summarizes the work.

\( \text{S3 a Earth and Space Sciences Concepts: The student produces evidence that demonstrates understanding of properties of Earth materials, such as...the properties of rocks and soils such as texture, color, and ability to retain water.} \)

A B C There is ample evidence that the students have an understanding of erosion.

\( \text{S4 a Scientific Connections and Applications: The student produces evidence that demonstrates understanding of big ideas and unifying concepts such as...cause and effect.} \)

A B C D These pieces and the ending also show a good understanding of cause and effect.

\( \text{S5 a Scientific Thinking: The student asks questions about natural phenomena; objects and organisms; and events and discoveries.} \)

D The entire investigation came from students’ questions about natural phenomena. The question and hypothesis are clearly stated.

\( \text{S5 e Scientific Thinking: The student identifies problems; proposes and implements solutions; and evaluates the accuracy, design, and outcomes of investigations.} \)

E The conclusion shows that students were focused on the best combination of grasses and soils to prevent erosion.

\( \text{S6 a Scientific Tools and Technologies: The student uses technology and tools...} \)

F G H I J K L The stream table was used effectively to gather data.
Attention to accuracy is evident throughout; these are but two examples.

Scientific Communication: The student represents data and results in multiple ways, such as... diagrams...and...writing.

The diagrams and accompanying explanations clearly describe the results of the investigations.

Scientific Communication: The student uses facts to support conclusions.

Throughout the work, but particularly in the conclusion, the generalizations follow directly from the data.

Scientific Communication: The student communicates in a form suited to the purpose and the audience, such as writing instructions that others can follow.

The procedures are well explained.

The attention to detail, and the recording and use of qualitative and quantitative data, support the judgment of this work as standard setting. Evidence of conceptual and applied understanding of Earth science is shown throughout.

**STREAM TABLE PLAN**

We are going to find out what happens when we put houses at the end of the drain.

We will need these materials:

- Stream table
- Water cup with hole
- Ruler
- 3 houses

We will not use any long sticks:

1. Place ruler on top of the stream table about the stream table from the end of the stream table.
2. Balance the cup on the end of the stream table at the ruler.
3. Drop it into the cup and watch what happens.
4. Repeat steps 1-3 until the water level is equal to the stream table.
Erosion

**STREAM TABLE MAP**

This is an investigation of erosion

1. hole is on the edge
2. the sand is sliding down
3. formed a channel
4. two houses fell down

**STREAM TABLE MAP**

This is an investigation of erosion

1. hole formed
2. sand channelled
3. tunnel closed
4. tunnel opened again
5. it's over, more sand down

**STREAM TABLE MAP**

This is an investigation of erosion

1. made a little hole
2. hole grew bigger
3. water was going to side
4. water was going forward
5. hole is filled in
6. water looks like milk

**STREAM TABLE MAP**

This is an investigation of erosion

1. hole cleaned
2. sand channelled
3. tunnel closed
4. tunnel opened again
5. it's over, more sand down

**Experiment Results**

Soils without grass:

The sandy soil eroded through two channels that the water made.

The topsoil eroded through one channel. At the bottom of stream table is where you would find all and organic material.

The clay soil eroded just a little bit. A little channel was made and little organic material eroded.
Results: Loosely fit with your.
The task
The National Student Research Center encourages the establishment of student research centers in
schools in the United States and around the world. The Center facilitates the exchange of information
by publishing a journal of student investigations and by use of the Internet (nsrcms@aol.com). It
provides a standard format that students use
to report their results. The format requires that
students state a purpose and hypothesis; report
their methods, data analysis, and conclusions;
and suggest applications for their results.

Circumstances of performance
This sample of student work was produced
under the following conditions:
alone
in a group
in class
as homework
with teacher feedback
with peer feedback
timed
opportunity for
revision

What the work shows
By investigating the optimum temperature for the
growth of yeast, the investigation explores character-
istics of organisms, particularly survival and
environmental support, but the report does not
explain why temperature or any other variable
would be important to investigate, so the work does not
illustrate conceptual understanding in Life Sciences
Concepts. It does not illustrate misunderstanding
either, however. The student does not mention sugar,
but has followed the instructions on the package.

Although sugar is necessary for “proofing” yeast, it
is not necessary for “activation.” The package indi-
cates that the yeast be “dissolved in water (1/4 cup)
at a temperature between 105 and 115 degrees
Fahrenheit. If it is to be proofed (foamy), a teaspoon
of sugar is added. After five minutes in warm water,
the yeast will begin to multiply with added food.”

55a  Scientific Thinking: The student asks questions about natural phenomena....

55b  Scientific Thinking: Use questions about natural phenomena.

55c  Scientific Thinking: Use evidence from reliable sources to construct explanations.

55d  Scientific Thinking: Evaluate the accuracy, design, and outcomes of investigations.

56a  Scientific Tools and Technologies: Use technology and tools.

56b  Scientific Tools and Technologies: Collect and analyze data.

56c  Scientific Investigation: An experiment, such as conducting a fair test.
Yeast Growth

Scientific Tools and Technologies: The student uses technology and tools (such as...microscopes) to gather data and extend the senses.

“On a slide” implies that a microscope was used. The procedure of using a microscope to count cells and the persistence shown by counting 232 cells while viewing them through a microscope is impressive use of scientific tools and technologies for an elementary student.

Scientific Tools and Technologies: The student collects and analyzes data using concepts and techniques in Mathematics Standard 4, such as...variability....

The student found the maximum of 100 degrees. At a more advanced level, a more “sophisticated” analysis would be expected: one that shows that the results at 100 degrees and 110 degrees are essentially the same. Further, students might study the way that yeast solutions cool slightly during use, so that it is good to start with a somewhat higher water temperature than recommended on the package; some recipes call for water at 120 to 130 degrees.

Scientific Investigation: The student demonstrates scientific competence by completing an experiment, such as conducting a fair test.

A full investigation includes:

• Questions that can be studied using the resources available.

• Procedures that are safe, humane, and ethical; and that respect privacy and property rights.

• Data that have been collected and recorded (see also Science Standard 6) in ways that others can verify and analyze using skills expected at this grade level (see also Mathematics Standard 4).

• Data and results that have been represented (see also Science Standard 7) in ways that fit the context.

• Recommendations, decisions, and conclusions based on evidence.

• Acknowledgment of references and contributions of others.

The work includes references to the package instructions.

• Results that are communicated appropriately to audiences.

• Reflection and defense of conclusions and recommendations from other sources and peer review.

By sharing the work on the Internet, the student is publishing the work and asking for feedback.

Measurement issues related to repeated sampling from the same container, repeated trials, and checking the temperature of the water would be expected of a middle school student but are not expected at the elementary level. Controlling the time allowed for growth is explicitly mentioned. Controlling the shape of the container and the amount of sugar are not mentioned.

The conclusion, that the hypothesis should be rejected is correct. The idea that the hypothesis was not intelligent and that the student would have had a basis better than the package instructions is not warranted. The fact that the package could have been correct and the temperature measurements could have been flawed in some way (inaccurate thermometer, for example) is an alternative explanation for the data. As noted above, however, analysis of some of the measurement issues is more sophisticated than would be expected for an elementary student. Finally, the willingness to report a result different from the hypothesis is a major accomplishment for an elementary student.
The task
The National Student Research Center encourages the establishment of student research centers in schools in the United States and around the world. The Center facilitates the exchange of information by publishing a journal of student investigations and by use of the Internet (nsrcmms@aol.com). It provides a standard format that students use to report their results. The format requires that students state a purpose and hypothesis; report their methods, data analysis, and conclusions; and suggest applications for their results.

Circumstances of performance
This sample of student work was produced under the following conditions:

alone in a group
in class as homework
with teacher feedback with peer feedback
timed opportunity for revision

What the work shows
As part of their work in mathematics, fourth grade students chose to gather data on sizes of different body parts and to compare their data with first grade students. Having done so, they then used the Internet to locate a seventh grade class that was willing to provide comparable data to see if the same pattern continued with age. They then “published” their work by reporting it on the Internet in the standard format.

55a Scientific Thinking: The student asks questions about natural phenomena....

A Questions about body sizes are of great interest to children. The value of allowing students to formulate their own questions is demonstrated by their including “smiles” in their list of body parts, something that would not occur to many adults.

55c Scientific Thinking: The student uses evidence from reliable sources to construct explanations.

B The students used data from their previous study with first graders to construct a hypothesis for seventh graders.
Scientific Thinking: The student evaluates different points of view using relevant experiences, observations, and knowledge.

The students checked their data against their prediction, which had been based on a reasonable idea that comparable rates of growth would be observed over three year spans prior to and following their age. They were surprised by their results. Attempting to explain the unexpected results, that the seventh graders had smaller heads and smiles, by critiquing the measurement procedure, would have provided more complete evidence for this standard.

Scientific Thinking: The student works individually and in teams to collect and share information and ideas.

These students went beyond their immediate experience by seeking out a seventh grade class so that they could extend their study beyond the grade levels contained in their elementary school. Working as a class and with other classes, even classes outside their own school, demonstrates the beginnings of a scientific community that shares data and publishes results.

Scientific Tools and Technologies: The student acquires information from multiple sources such as non-print sources and from experimentation.

Information was acquired electronically and by direct measurement.

The other aspects of the Scientific Tools and Technologies standard are not fully realized. The tools are not identified, nor are the procedures for measuring (e.g., Were smiles measured at their greatest length? Corner to corner or edge of lips?), but measurements are reported in a reasonable way. The middle school students, who measured themselves, reported with more significant digits, which is probably appropriate. The results of the analysis are reported here but not the procedures. A full report of the data would reveal the adequacy of the sample and the appropriateness of using the average.

Scientific Communication: The student represents data and results in multiple ways, such as numbers, tables, and...writing.

The data are presented in both a text and a table. A bar graph might have been an effective way to show the contrast from first to fourth to seventh grade, though it would be difficult to convey in many Internet environments.

Scientific Communication: The student uses facts to support conclusions.

Scientific Communication: The student communicates in a form suited to the purpose and the audience.

The report is formatted to follow the NSRC guidelines completely and clearly.

The report is not a full investigation consistent with the Scientific Investigation standard. Attempting to explain the unexpected results, that the seventh graders had smaller heads and smiles, by critiquing the measurement procedure, would have provided more complete evidence of an investigation. Attempting to explain the results, by pursuing, for example, developmental reasons for heads attaining their adult size in babies and children more rapidly than limbs do, would have taken the investigation into the Life Sciences Concepts standard. Dealing with the size and representativeness of the sample and the analysis of the data would have addressed parts of Mathematics Standard 4, Statistics and Probability Concepts.
Work Sample & Commentary: Aquarium

The task
Given a drawing of an aquarium with six labeled items (light, thermometer, castle, rock, snail, and plant), students were told: “In the picture of an aquarium above, six items are labeled. Which of the six items are important to use in or with an aquarium? Explain why each one you name is important.”

Circumstances of performance
This sample of student work was produced under the following conditions:

- alone
- in a group
- in class
- with teacher feedback
- with homework
- timed (20 minutes)
- opportunity for revision

The task was part of a state assessment program and unrelated to the curriculum that the students were studying.

What the work shows
S2a Life Sciences Concepts: The student produces evidence that demonstrates understanding of the characteristics of organisms, such as survival and environmental support.

This response correctly identifies the role each labeled item plays in the environment and connects the item to the needs of the fish. For a fairly straightforward question, the response provides elaborations that show a depth of understanding.

A The explanation of the role of the plant is very complete for the elementary level, since specifying either function would have been adequate.

B The elaboration of the function of the thermometer shows a good degree of accuracy for the elementary level.

C Objects such as the rock and the castle are used in aquaria for decoration as well as protection. From the drawing, one could argue that the fish are large enough not to need protection and that these objects are ornamental. That would also be a correct response.

D The language, “decomposing material,” is particularly precise for the elementary level.

E This reference to the function of the light is correct. It also helps the plant to grow. Although one might assume that the room’s ambient light would suffice for plant growth, this is a refinement appropriate for middle level, not for an elementary student producing a comprehensive response on a timed test.

The systematic treatment of all the items is also a strength at the elementary level. At the middle school level, it would be expected that students could provide a similar analysis for an environment with which they have less first hand experience.
Work Sample & Commentary: Snow Melt

The task
This work sample is from a student investigation for a science fair. The instructions asked the students to select a question they were interested in and required that some experiment be performed to gather data and come to a conclusion. An explanation of the scientific concepts involved in the experiment was not required. The science fair rules required that data be displayed in a poster presentation format.

Circumstances of performance
This sample of student work was produced under the following conditions:

- alone
- in group
- in class
- as homework
- with teacher feedback
- with peer feedback
- timed
- opportunity for revision

This work sample illustrates a standard-setting performance for the following parts of the standards:

- Scientific Thinking: Ask questions about natural phenomena.
- Scientific Thinking: Use evidence from reliable sources to construct explanations.
- Scientific Thinking: Evaluate the accuracy, design, and outcomes of investigations.
- Scientific Tools and Technologies: Use technology and tools.
- Scientific Tools and Technologies: Collect and analyze data.
- Scientific Communication: Represent data and results in multiple ways.
- Scientific Communication: Use facts to support conclusions.
- Scientific Communication: Communicate in a form suited to the purpose and the audience.
- Scientific Investigation: An experiment, such as conducting a fair test.

What the work shows

- Scientific Thinking: The student asks questions about natural phenomena.
- Scientific Thinking: The student uses evidence from reliable sources to construct explanations.
  - A The statement of the hypothesis includes a rationale based on observation.
- Scientific Thinking: The student evaluates the accuracy, design, and outcomes of investigations.
  - B The reasoning about the results, both “I have no reason for it,” and “2 possible reason(s),” shows a good degree of self-evaluation for the elementary level.
Scientific Tools and Technologies: The student uses technology and tools (such as...thermometers, watches)...to gather data and extend the senses.

Scientific Tools and Technologies: The student collects and analyzes data using concepts and techniques in Mathematics Standard 4, such as...data displays, graphing....

The calculation and display of the differences sets up an interesting analysis in the conclusion.

Scientific Communication: The student represents data and results in multiple ways, such as numbers, tables, and graphs....

Scientific Communication: The student uses facts to support conclusions.

Scientific Communication: The student communicates in a form suited to the purpose and the audience....

The format of the science fair was executed successfully.
Scientific Investigation: The student demonstrates scientific competence by completing an experiment, such as conducting a fair test.

A full investigation includes:

- Questions that can be studied using the resources available.
- Procedures that are safe, humane, and ethical; and that respect privacy and property rights.
- Data that have been collected and recorded (see also Science Standard 6) in ways that others can verify and analyze using skills expected at this grade level (see also Mathematics Standard 4).
- Data and results that have been represented (see also Science Standard 7) in ways that fit the context.
- Recommendations, decisions, and conclusions based on evidence.
- Acknowledgment of references and contributions of others.
- Results that are communicated appropriately to audiences.
- Reflection and defense of conclusions and recommendations from other sources and peer review.

The investigation includes a logical and sequential plan including multiple trials. It uses multiple representations and data displays to communicate scientific findings.

It explores different interpretations of data and applies the information to potentially relevant environmental conditions in concluding remarks.

It considers potentially confounding and uncontrolled variables in the experimental design in making appropriate conclusions based on experimental data.

The work touches on the concept of density. More evidence, such as an explanation of the relationship between density and melting times, would be required to meet the standard for Physical Sciences Concepts.

Snow Melt
Work Sample & Commentary: Fire-Belly Newts

The task
An elementary student participated in a 4-H program in which she raised an animal, learning about and caring for its needs. The culmination of this project involved a county-wide fair at which the student’s project was judged against other similar projects. The task involved observation of the animal, some library research, the production of a display, a report, and an interview with a judge. The student’s original report and a follow-up interview are included here.

Circumstances of performance
This sample of student work was produced under the following conditions:
- alone
- in class
- with teacher feedback
- timed

in a group
as homework
with peer feedback
opportunity for revision

The work was done in a 4-H program.

What the work shows
S2 a Life Sciences Concepts: The student produces evidence that demonstrates understanding of characteristics of organisms, such as survival and environmental support....

A

S2 b Life Sciences Concepts: The student produces evidence that demonstrates understanding of life cycles of organisms....

B

S2 c Life Sciences Concepts: The student produces evidence that demonstrates understanding of organisms and environments, such as the interdependence of animals and plants in an ecosystem....

C

S5 c Scientific Thinking: The student uses evidence from reliable sources to construct explanations.

C D The student used several sources and was able to identify what information came from which source.
**Scientific Thinking:**

The student evaluates different points of view using relevant experiences, observations, and knowledge; and distinguishes between fact and opinion.

The student differentiated between things she had read and things that she had observed.

**Scientific Communication:**

The student represents data and results in multiple ways, such as drawings, diagrams, and artwork; and technical and creative writing.

The student communicated with a drawing, a written report, a poster, an oral presentation, and through an interview.

**Scientific Communication:**

The student uses facts to support conclusions.

**Scientific Communication:**

The student communicates in a form suited to the purpose and the audience.

Consistent with the context of a 4-H project for presentation at a county fair, the student communicated with a drawing, a written report, a poster, an oral presentation, and an interview with the judge.

**Scientific Investigation:**

The student demonstrates scientific competence by completing a systematic observation, such as a field study.

A full investigation includes:

- Questions that can be studied using the resources available.

- Procedures that are safe, humane, and ethical; and that respect privacy and property rights.

**Fire-Belly Newts**

**Background:**

Newts are amphibians (can live on land and in water) and are related to salamanders, not lizards. They have four toes on their front and five on the back. They are very unique. The last 40% of their tail is for swimming purposes. They can survive freezing, but they cannot handle temperatures above freezing and above freezing. They are also poisonous. They can become by means of small. With picking up a newt, your hands can not be too hot.

CARE: The next is to read once a day. If you have read twice a month, in doing this is not to read and made off the right side of the book. I also have to show off the air pump.

**Nutrition:**

In the wild newts will eat small insects if a meal is moving it will eat moths of cloth.

FEEDING: (any, any more) In this strange pools. You find what can pull a day. The pools on back that in sunny when in a weather day. Science doesn’t usually use why we are looking. The pools in be filled. They can be bunged to one right of your hand. You can also put state or line up to make it looks like the head in above.

FEEDING: (any, any more) Here in a tank with a power filter, gravel and 2 large stones. They have to help between the two stones. Science had gone to school and the amazing lovely we have performed a small tank tank. The really are power completely filled with water. Like them to get on top of the large rocks and one of the stones.

HEALTH: I have read about in the 2 years, more accurate in five longer than that. The position is the shape. When the wild on land when made like a stomach. When they see small they look like a puppy.

**Maximum:**

They have a water shallow that only that particular temperature to average. They do a different range other water will recognize. Newts have a field they need in the water and the humans will follow the small behind the tank. Some weeks now develop a more on the tank raise and a sheep will during breeding season.

**Other Information:**

Newts can live in right when you grow and they should be a part of them. Then they eat. Their stomach is. The wild on physiologist, people, and under water materials. When they think they are gone they turn to their back. Their to breathe, oxygen, and gray on their back. Then they catch their surroundings. They also have a bad time that their able to spread off.

**Other Types of Newts:**

Some different kinds of people are: Japanese Newts (Newts born in a pond and in the pond, short and fat); Yellow Banded Newts (Newts born in a pond and in the pond, short and fat); Feeder Newts, Banded, and Polychromatides (Newts born in a pond and in the pond, short and fat).

**Characteristics:**

- SkinHyper: By Linda and Lisa
- Polychromatides: By Nancy and Lisa
- Feeder Newts: By Scott and Lisa
- Banded: By Linda
- Japanese Newts: By Bob and Lisa
- Japanese Newts: By Scott

**Other Information:**

Newts can live in right when you grow and they should be a part of them. Then they eat. Their stomach is. The wild on physiologist, people, and under water materials. When they think they are gone they turn to their back. Their to breathe, oxygen, and gray on their back. Then they catch their surroundings. They also have a bad time that their able to spread off.

**Feeder Newts:**

Newts are amphibians (can live on land and in water) and are related to salamanders, not lizards. They have four toes on their front and five on the back. They are very unique. The last 40% of their tail is for swimming purposes. They can survive freezing, but they cannot handle temperatures above freezing and above freezing. They are also poisonous. They can become by means of small. With picking up a newt, your hands can not be too hot.
Data that have been collected and recorded (see also Science Standard 6) in ways that others can verify and analyze using skills expected at this grade level (see also Mathematics Standard 4).

Data and results that have been represented (see also Science Standard 7) in ways that fit the context.

Recommendations, decisions, and conclusions based on evidence.

Acknowledgment of references and contributions of others.

Results that are communicated appropriately to audiences.

Reflection and defense of conclusions and recommendations from other sources and peer review.