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:

- S1 **Physical Sciences Concepts;**
- S2 **Life Sciences Concepts;**
- S3 **Earth and Space Sciences Concepts;**
- S4 **Scientific Connections and Applications;**
- S5 **Scientific Thinking;**
- S6 **Scientific Tools and Technologies;**
- S7 **Scientific Communication;**
- S8 **Scientific Investigation.**

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 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 Volume 1, 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 page 86). 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.

Complementing the conceptual understanding standards, S5 - S8 focus on areas of the science curriculum that need particular attention and a new or renewed emphasis:

- S5 **Scientific Thinking;**
- S6 **Scientific Tools and Technologies;**
- S7 **Scientific Communication;**
- S8 **Scientific Investigation.**

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, S6, Scientific Tools and Technologies, 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 partners have made a commitment to create the learning environments where students can develop the knowledge and skills that are delineated here, we hope that making these requirements explicit will help those who allocate resources to understand the consequences of their actions in terms of student performance.

Performance Descriptions *Science*

To see how these performance descriptions compare with the expectations for elementary school and middle school, turn to pages 160-167.

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.

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 Structure of atoms, such as atomic composition, nuclear forces, and radioactivity.

S1 b Structure and properties of matter, such as elements and compounds; bonding and molecular interaction; and characteristics of phase changes.

S1 c Chemical reactions, such as everyday examples of chemical reactions; electrons, protons, and energy transfer; and factors that affect reaction rates such as catalysts.

S1 d Motions and forces, such as gravitational and electrical; net forces and magnetism.

S1 e Conservation of energy and increase in disorder, such as kinetic and potential energy; energy conduction, convection, and radiation; random motion; and effects of heat and pressure.

S1 f Interactions of energy and matter, such as waves, absorption and emission of light, and conductivity.

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

Debate the relative merits of harnessing nuclear fission and fusion as energy sources. **1a, 1b, 1c, E3b**

Predict the age of a hypothetical fossil based on the rate of radioactive decay of several radioactive isotopes. **1a, 2c, 3a, 3b, 3c, 3d**

Research the history of the periodic table; take and defend a position on the configuration that best illustrates properties of elements. **1a, 1b, 1c, 4e**

Determine the characteristics for a dinner table candle that will keep the candle burning longer. **1c, 1e**

Explain why a local urban area has smog and what can be done about it. **1a, 1b, 1c, 1e, 4d**

Make an informational videotape describing how an understanding of acceleration and velocity can make one a better driver. **1d, 1e, 7d**

Explain how electric motors and generators illustrate the relationship between electricity and magnetism. **1c, 1d, 1e, 4a, 4b**

Explain to a younger student the difference between temperature and heat. **1e, 7d**

Compare the efficiency and energy consumption of several different methods of generating electricity that could be used locally. **1e, 1f, 4b, 4d**

Earn the Energy Merit Badge (Boy Scouts of America) and explain how it helped you to understand the interactions of matter and energy. **1f, 4b, 4d**

Trace the transformations of energy from the electric current that enters a CD player or boombox to a sound that can be heard as music. **1f, 4b**

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 The cell, such as cell structure and function relationships; regulation and biochemistry; and energy and photosynthesis.

S2 b Molecular basis of heredity, such as DNA, genes, chromosomes, and mutations.

S2 c Biological evolution, such as speciation, biodiversity, natural selection, and biological classification.

S2 d Interdependence of organisms, such as conservation of matter; cooperation and competition among organisms in ecosystems; and human effects on the environment.

S2 e Matter, energy, and organization in living systems, such as matter and energy flow through different levels of organization; and environmental constraints.

S2 f Behavior of organisms, such as nervous system regulation; behavioral responses; and connections with anthropology, sociology, and psychology.

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

Create a picture book to explain how a producer converts solar energy to chemical energy through an ecosystem. **2a, 1c, 3a**

Explain how cell functions are regulated to allow organisms to respond to the environment and to control and coordinate growth and differentiation. **2a, 2b, 2c, 2f, 1c**

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**

Create a working model to show how the instructions for specifying an organism's characteristics are carried in DNA and its subunits. **2b, 2c, 5c**

Make a videotape debating the possible explanations for the extinction of dinosaurs. **2c, 2d, 7d**

Make a storyboard and give a presentation to younger students explaining the increasing prevalence of dark forms of moths 150 years ago and the more recent return to light forms. **2b, 2c, 2d, 7d, E3c**

Make a humorous travel brochure describing the pathway of a carbon dioxide molecule and an oxygen molecule through the living and non-living components of the biosphere. **2e, 1b**

Earn the Ecology Merit Badge (Girl Scouts of the U.S.A.) or the Environmental Science Merit Badge (Boy Scouts of America) and explain how it helped you to understand the interdependence of organisms. **2d, 2e**

Trace a candy bar from the time it is purchased to the time it is completely expended. **2e**

Develop a recycling outreach program as part of a community service project to illustrate the limited availability of matter and energy in the ecosystem. **2c, 2d, 1c, 4b**

Conduct an investigation to determine how different kinds of plants respond to various environmental stimuli. **2f**

Research the development of, and recent advances in the theory of, evolutionary psychology. **2c, 2f, 4e**

S3 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 Energy in the Earth system, such as radioactive decay, gravity, the Sun's energy, convection, and changes in global climate.

S3 b Geochemical cycles, such as conservation of matter; chemical resources and movement of matter between chemical reservoirs.

S3 c Origin and evolution of the Earth system, such as geologic time and the age of life forms; origin of life; and evolution of the Solar System.

S3 d Origin and evolution of the universe, such as the "big bang" theory; formation of stars and elements; and nuclear reactions.

S3 e Natural resource management.

Examples of activities through which students might demonstrate conceptual understanding of Earth and space sciences include:

Make a brochure providing an orientation to the climate of the local region to a newcomer; and explain the likely weather in that context. **3a**

Explain the relationship between gravity and energy. **3a, 1d**

Analyze the risk of natural disasters in the local region and make recommendations for actions that can be taken to mitigate the damage. **3a, 3b, 4b**

Germinate seeds on a rotating platform and explain the observed growth pattern. **3a, 1d, 2e**

Conduct a study of the geology of an area near the school; and describe the likely history of the region, using observations and reference materials. **3b, 3c**

Diagram the birth, development, and death of a human; contrast with the geologic time frame of the origin and evolution of the Earth system or the universe. **3c, 3d, 2c**

Work with other students to become an "expert panel" to describe the historical events leading to the development of the "big bang" theory. **3c, 3d, 5f**

Write a research paper to explain how stars produce energy from nuclear reactions and how these processes led to the formation of other elements. **3d, 1a, 1b, 1c, 1f, E2a**

Identify a place that is subject to periodic flooding, evaluate its positive and negative effects, and study different ways of maintaining, reducing, or eliminating the likelihood of flooding. **3e**

S4 Scientific Connections and Applications

The student demonstrates conceptual understanding by using the concept 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 the reciprocal relationship between science and technology; the development of agricultural techniques; and the reasonableness of technological designs.

S4 c Health, such as nutrition and exercise; disease and epidemiology; personal and environmental safety; and resources, environmental stress, and population growth.

S4 d Impact of technology, such as constraints and trade-offs; feedback; benefits and risks; and problems and solutions.

S4 e Impact of science, such as historical and contemporary contributions; and interactions between science and society.

Examples of activities through which students might demonstrate conceptual understanding of scientific connections and applications include:

Construct a computer-controlled robot arm that mimics the form and function of a human hand and forearm. **4a, 4b, 4c, 2a**

Work with other students to give a presentation based on scientific principles arguing for a systemic solution to an environmental problem that concerns the school or community. **4a, 4b, 4c, 4d, 1a, 2d, 2e, A1b**

Propose modifications to improve skateboards, in-line skates, bicycles, or similar objects to make them safer, faster, or less expensive. **4b, 4c, 1a, A1b**

Conduct a study of the school cafeteria including: food storage and preparation, nutrition, and student preferences; and make recommendations for improvement. **4c, 4d**

Debate the positive and negative consequences of a recently developed technological innovation. **4b, 4d, 4e, E3b**

Earn the Food, Fibers, and Farming Merit Badge (Girl Scouts of the U.S.A.) and make a poster that shows understanding of agriculture or technology. **4b, 4c, 4d, 4e**

Samples of student work that illustrate standard-setting performances for these standards can be found on pages 86-105.

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 high school 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.

S5 Scientific Thinking

The student demonstrates skill in scientific inquiry and problem solving by using thoughtful questioning and reasoning strategies, common sense and diverse conceptual understanding, and appropriate ideas and methods to investigate science; that is, the student:

S5 a Frames questions to distinguish cause and effect; and identifies or controls variables in experimental and non-experimental research settings.

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 develop descriptions, explanations, and models; and makes appropriate adjustments and improvements based on additional data or logical arguments.

S5 d Proposes, recognizes, analyzes, considers, and critiques alternative explanations; 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 skill in scientific thinking include:

Evaluate the claims and potential benefits and risks of steroid use and apply the scientific evidence to a reported "case study" of an athlete. **5a, 5b, 5c, 5d**

Predict how long a plant will live, planted in moist soil in a closed glass jar located by a window; explain what additional information would be needed to make a better prediction. **5a, 5b, 5c**

Compare and contrast the nutritional value of several common brands of cereals. **5b, 5c, 5d**

Compare and contrast lines of evidence for theories of dinosaur extinction. **5b, 5c, 5d, 2c, 2d**

Explain the chain of inference in DNA testing and debate both positions regarding its inclusion as evidence in a capital trial. **5c, 5d, 1b, 1c, 2a, 2b, 4d**

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 Uses technology and tools (such as traditional laboratory equipment, video, and computer aids) to observe and measure objects, organisms, and phenomena, directly, indirectly, and remotely, with appropriate consideration of accuracy and precision.

S6 b Records and stores data using a variety of formats, such as data bases, audiotapes, and videotapes.

S6 c Collects and analyzes data using concepts and techniques in Mathematics Standard 4, such as mean, median, and mode; outcome probability and reliability; and appropriate data displays.

S6 d Acquires information from multiple sources, such as print, the Internet, computer data bases, and experimentation.

S6 e Recognizes and limits sources of bias in data, such as observer and sample biases.

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

Work with other students to repeat a historical series of experiments, such as those leading to the current understanding of photosynthesis, and write an essay comparing and contrasting the differences in available tools and technologies. **6d, 2a, 4d, 4e, 5c, 7b**

Evaluate the accuracy and timeliness of information reported during the "life" of a hurricane or tropical storm. **6d, 3a, 4a, 5c**

Use the Internet to get current information on a rapidly changing scientific topic. **6d**

Use a computer interface to measure the velocity of objects. **6d, 1d, 5c**

Use telecommunications to compare data on similar investigations with students in another state. **6d**

Earn the Orienteering Merit Badge (Boy Scouts of America) and teach another student what to do if he or she gets lost. **6d, 3a, 5c, 7d**

To see how these performance descriptions compare with the expectations for elementary school and middle school, turn to pages 160-167.

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; technical and creative writing; and selects the most effective way to convey the scientific information.

S7 b Argues from evidence, such as data produced through his or her own experimentation or data produced by others.

S7 c Critiques published materials, such as popular magazines and academic journals.

S7 d Explains a scientific concept or procedure to other students.

S7 e Communicates in a form suited to the purpose and the audience, such as by writing instructions that others can follow; critiquing written and oral explanations; and using data to resolve disagreements.

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

Analyze a ballot initiative on a local endangered species. **7a, 7b, 2c, 4d, 5a**

Critique a *Time* article which reports on something you have studied. **7c**

Make a "claymation" video illustrating in simple terms how a virus attacks the human body. **7c, 2d, 4c, 5c**

Give an oral report describing the change over time in local air quality. **7d, 2d, 3e, 4d, E3c**

Earn the Model Design and Building Merit Badge (Boy Scouts of America) and explain what constitutes an effective model. **7d, 4b, 5c**

Write an advertisement for a cold relief product that explains how it works. **7e, 4c, 5c, 5d, 6d**

S8 Scientific Investigation

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

S8 a Controlled experiment.

S8 b Fieldwork.

S8 c Design.

S8 d Secondary research.

A single project may draw on more than one type 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 analyzed 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:

Investigate the effectiveness of common household cleaners on bacterial growth. **8a, 1c, 2a, 4c**

Conduct research to determine if the incidence of asthma is related to weather. **8b, 3a, 4c**

Conduct a study of the geology of an area near the school and describe the likely history of the region, using observations and reference materials. **8b, 8d, 3c, 6d**

Compare and contrast the designs of different sports shoes and evaluate the designs considering the varying demands of different sports. **8c**

Conduct an investigation to determine if the shape of a stereo speaker container affects sound quality. **8c, 1f**

Study the distribution of a species in the region or state and discuss the likelihood of it becoming endangered. **8d, 2c, 5c, 6c**

Samples of student work that illustrate standard-setting performances for these standards can be found on pages 86-105.

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 high school 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: *Density of Sand*

The quotations from the Science performance descriptions in this commentary are excerpted. The complete performance descriptions are shown on pages 82-85.

The task

This work sample was an entry in a Golden State Examination Science Portfolio for the category "problem solving investigation." Students were required to submit a piece of work and the "Self-Reflection Sheet." In this case, the student designed and conducted an investigation to determine the density of sand.

Circumstances of performance

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

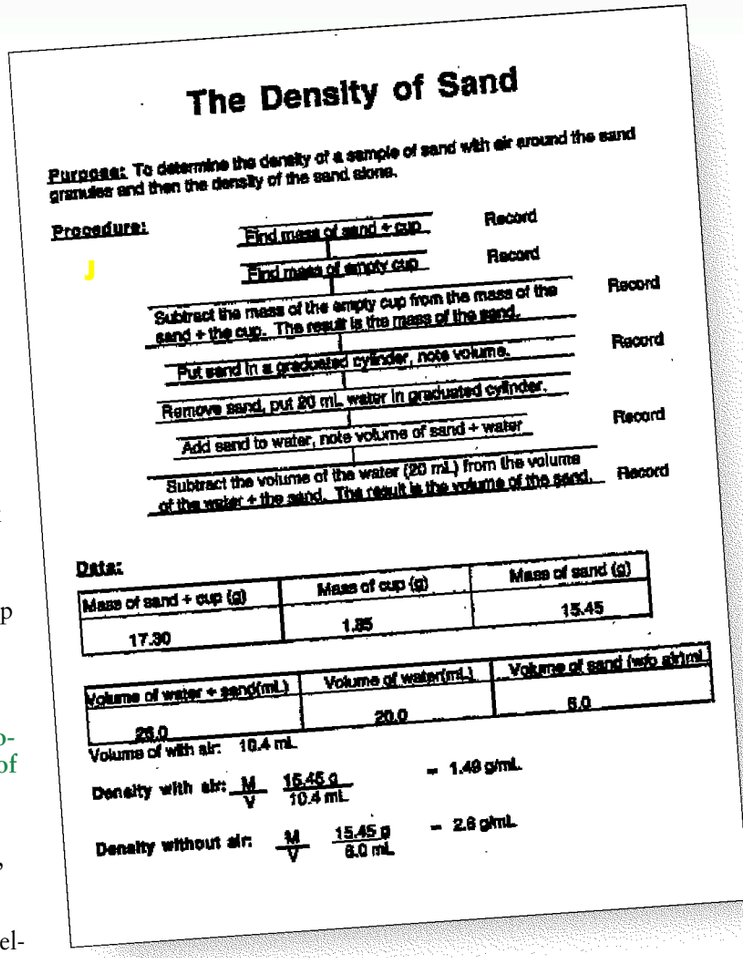
alone	in a group
in class	as homework
with teacher feedback	with peer feedback
timed	opportunity for revision

The work was done with a partner and written up individually.

What the work shows

S1 b Physical Sciences Concepts: The student produces evidence that demonstrates understanding of the structure and properties of matter....

A B C Throughout the work, the student explained the relationship between mass, volume, and density, often with a level of detail revealing excellent conceptual understanding. There is also ample evidence that the student appreciated the relevance of density in everyday situations.



The Density of Sand

Purpose: To determine the density of a sample of sand with air around the sand granules and then the density of the sand alone.

Procedure:

J

Find mass of sand + cup — Record

Find mass of empty cup — Record

Subtract the mass of the empty cup from the mass of the sand + the cup. The result is the mass of the sand. — Record

Put sand in a graduated cylinder, note volume. — Record

Remove sand, put 20 mL water in graduated cylinder.

Add sand to water, note volume of sand + water — Record

Subtract the volume of the water (20 mL) from the volume of the water + the sand. The result is the volume of the sand. — Record

Data:

Mass of sand + cup (g)	Mass of cup (g)	Mass of sand (g)
17.30	1.85	15.45

Volume of water + sand(mL)	Volume of water(mL)	Volume of sand (w/o air)mL
26.0	20.0	6.0

Volume of with air: 10.4 mL

Density with air: $\frac{M}{V}$ $\frac{15.45\ g}{10.4\ mL}$ = 1.49 g/mL

Density without air: $\frac{M}{V}$ $\frac{15.45\ g}{6.0\ mL}$ = 2.6 g/mL

S5 a Scientific Thinking: The student frames questions to distinguish cause and effect; and identifies or controls variables in experimental and non-experimental research settings.

D Here and throughout, the work displays evidence of appropriate scientific thinking and use of experimental data to reach conclusions.

S5 e Scientific Thinking: The student identifies problems; proposes and implements solutions; and evaluates the accuracy, design, and outcomes of investigations.

E F G The student continually evaluated and critiqued the appropriateness of the experimental design and the accuracy of the measuring process, and described the situations in which the techniques employed would be most effective.

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

- **S1 b Physical Sciences Concepts: Structure and properties of matter.**
- **S5 a Scientific Thinking: Frame questions to distinguish cause and effect; and identify or control variables.**
- **S5 e Scientific Thinking: Evaluate the accuracy, design, and outcomes of investigations.**
- **S5 f Scientific Thinking: Work individually and in teams.**
- **S6 a Scientific Tools and Technologies: Use technology and tools.**
- **S7 e Scientific Communication: Write instructions that others can follow.**

Density of Sand

Calculations and Analysis:

1. This lab was conducted using sand sample A. The mass of the sand was found by finding the mass of the sand in the cup, and then subtracting the mass of the cup. The mass of the sand was 15.43 g. The sand's volume with air, which was found by placing the sand in a graduated cylinder, was 10.4 mL. The sand's volume without air, which was found using the water displacement method, was 6.0 mL.

I

2. The density of the sand with air was found to be 1.49 g/ mL, and the density of the sand alone was 2.6 g/mL. The sand with the air had a lower density than the sand alone. The equation for density is mass divided by volume. For both density calculations, the mass of the sand was the same. However, the volume of the sand with the air was larger than the volume of the sand alone. This is because the grains of sand were separated by air, which made the volume larger than it would be if air was not present. Since the volume of the sand with air was larger, it had a lower density.

A

D

3. Our answers were compared with those of four other groups.

group #1:	density with air	1.4 g/ mL
	density without air	2.5 g/ mL
group #2	density with air	0.65 g/ mL
	density without air	1.02 g/ mL
group #3	density with air	3.0 g/ mL
	density without air	1.5 g/ mL
group #4	density with air	1.49 g/mL
	density without air	2.73 g/mL

E

4. Three out of the four groups we compared results with had answers very similar to our own. One group, #2, had results that were very different. Since density is an intensive property, the difference in sample sizes among the other groups should not have affected the results. Other groups also may have made errors in their measurements or in their procedures. By double-checking each group's measurements and calculations, it would be possible to determine which group had the most accurate results.

F

5. The procedure utilized in this lab would work well for small, irregular solids such as sand. Many objects, however, would be far too large to place in a graduated cylinder and use the water displacement method. In their instance larger containers could be used. It also would also be much easier to determine the density of regular solids using calculations of length, width, and other dimensions in conjunction mathematical formulas. This method was extremely successful in this example.

S5 f Scientific Thinking: The student works individually and in teams to collect and share information.

E Comparison of results among groups provided partial confirmation of results.

H The student has acknowledged the benefits of collaboration.

S6 a Scientific Tools and Technologies: The student uses technology and tools (such as traditional laboratory equipment…) to…measure objects directly, indirectly…, and with appropriate consideration of accuracy and precision.

I The student used traditional methods and

F understood them.

E Comparison of results among groups was an effective method for judging accuracy.

S7 e Scientific Communication: The student communicates in a form suited to the purpose and the audience, such as by writing instructions that others can follow….

J

GSE Self-reflection Sheet

GSE Self-reflection Sheet: Problem-solving Investigation

1. *Thoroughly* explain the scientific concept you are investigating in this entry. Give specific examples that show how this concept relates to your Problem-solving Investigation.

The purpose of this experiment was to determine the density of sand with air around it and the density of sand alone. The main concept in this lab is how the density of a substance is affected by its mass and volume, namely through the presence or the absence of air around the sand when determining the volume of the sample. This investigation introduces the idea that density is an intensive property, a concept that is reinforced by providing for different groups to use varied amounts of sand when performing these calculations. Density of a given substance remains constant regardless of the size of the sample used./

B

2. Describe, *in detail*, the part or parts of this investigation YOU personally designed.

This lab contained only a purpose, not a procedure. It was up to the students to design the entire method of determining the density of the sand both with and without air. I designed the plan to use the water displacement method for the volume of the sand without air, and to simply place the sand in a graduated cylinder in order to find it's volume with air. Please see the procedure section on page 1.

3. Describe how the scientific concept you investigated in this component is related to a real-world issue or personal experience (you may include issues that affect society or the environment).

The difference in density of objects around us is an integral part of our world. It would be rather difficult to float in the bathtub if water's density were as low as that of air, and just as difficult if water had a density similar to that of a solid. In the same way, it is crucial to our way of thinking and living that density be an intensive property. If the density of a given substance varied with the size of the sample measured, the results could be catastrophic. Imagine buying a 4"x4"x4" block of wood with which to build your home, and finding it to be of a much different consistency and stability than a 50"x50"x50" block of the same type of wood! Everyday we rely on the properties of density for our most basic functions and activities. This experiment simply made us aware of them.

C

GSE Self-reflection Sheet: Problem-solving Investigation (cont'd)

4. Describe how working with others on this investigation helped to increase your understanding of science.

Although a hypothesis was not necessary in this investigation, my group worked together to develop a procedure in order to fulfill the purpose of this experiment. My partner and I brainstormed for a great length of time, debating the most efficient set-up and procedures to achieve the most accurate results. This involved many ideas being rejected as inefficient or inaccurate. For example, our first instinct was to simply spill the sand out onto the triple beam balance when determining its mass. Careful thought and discussion, however, caused us to realize that this would result in lost sand and therefore inaccurate results. We then devised a more accurate plan of weighing the sand within the cup, and then removing the sand from the cup and weighing the cup alone. We then subtracted the mass of the empty cup from the mass of the cup and the sand, and indirectly determined the mass of the sand. The entire procedure for this investigation was the result of a collaborative effort between my partner and I.

G

5. What did you conclude from the investigation? Was the conclusion the same as or different from what you expected? Describe how your observations and data support your conclusions.

From this investigation, we concluded that a sample of sand has a lower density when it is surrounded by air than when air is not present. My partner and I found sand surrounded by air to have a density of 1.49 g/mL, whereas sand that was not surrounded by air had a density of 2.6 g/mL. My partner and I found it interesting to discover that the presence or absence of air affects the density of a substance. This discovery was shown by the difference in our calculations of the density of the sand with air and without air. By comparing our results with those of other lab teams, we concluded that density is an intensive property. Although all of the teams used different amounts of sand in their calculations, their results were very similar, and in some cases identical to our own. This means that the density of a given substance does not change with the size of the sample measured.

H In chemistry, as in most areas in life, collaborative efforts achieve the most accurate results in the most efficient manner. Working with a partner or a with a group enables individuals to master concepts and ideas that would be difficult or impossible for them to understand on their own. While brainstorming ideas for the procedure, my partner and I were able to "bounce" ideas off of one another and receive feedback and new ideas in return. In the same manner, if one partner had overlooked a small detail that might impede the obtaining of accurate results, the second partner was quick to see that potential problem and propose a solution. Through exchanging ideas, critique, questions, and information, my partner and I were able to understand the concepts presented in this investigation.

Work Sample & Commentary: *Photosynthesis*

The quotations from the Science peformance descriptions in this commentaryare excerpted. The complete performance descriptions are shown on pages 82-85.

The task

This work sample was an entry in a Golden State Examination Science Portfolio for the category "Problem-solving investigation." Students were required to submit a piece of work and the "Self-Reflection Sheet." In this case, the student designed and conducted an investigation of the factors that affect the rate of photosynthesis.

Circumstances of performance

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

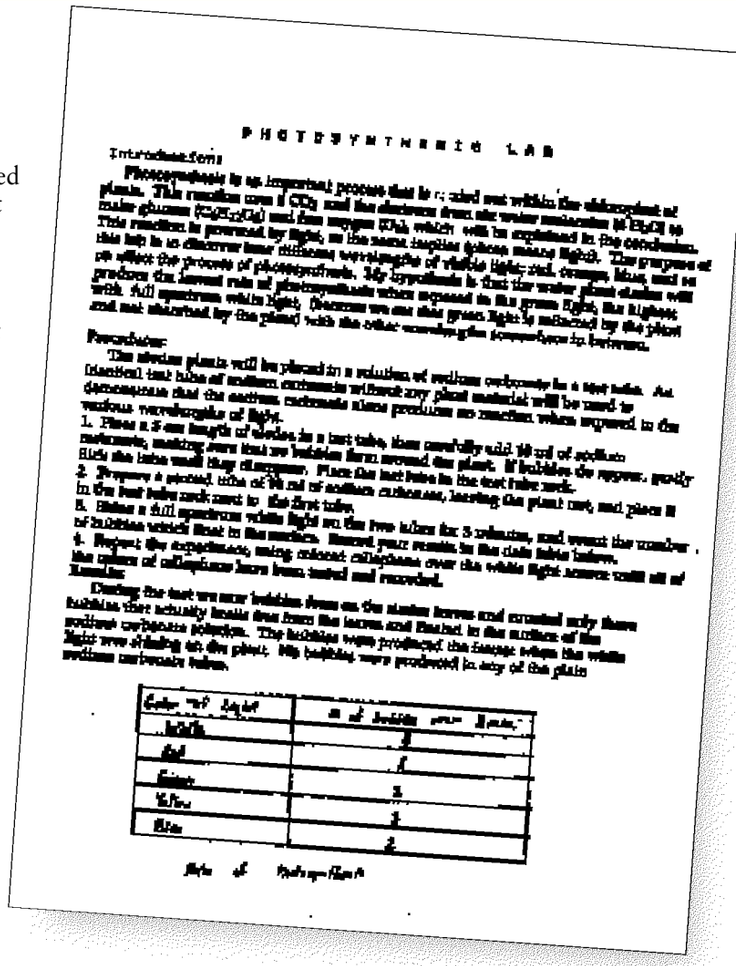
alone	in a group
in class	as homework
with teacher feedback	with peer feedback
timed	opportunity for revision

The work was done with a partner and written up individually. It followed a unit on biochemistry and photosynthesis.

What the work shows

S1 c Physical Sciences Concepts: The student produces evidence that demonstrates understanding of chemical reactions, such as…electrons, protons, and energy transfer….

A B In his descriptions of photosynthesis, the student explained the chemical reactions and interactions of energy and matter, often with sophisticated detail. This understanding is evident throughout the work.



PHOTOSYNTHESIS LAB

Introduction:

Procedure:

Reproduced by permission. Copyright, California Department of Education.

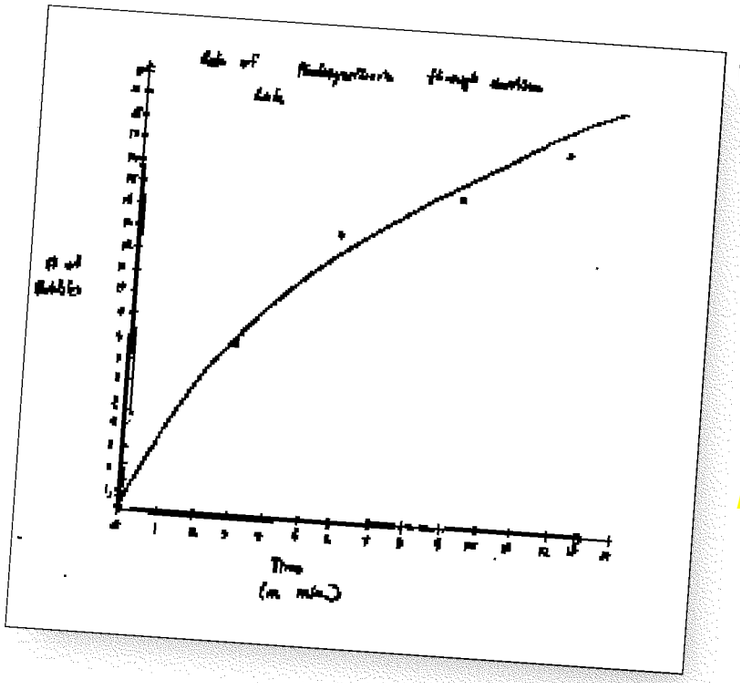
S1 f Physical Sciences Concepts: The student produces evidence that demonstrates understanding of interactions of energy and matter, such as waves, absorption and emission of light, and conductivity.

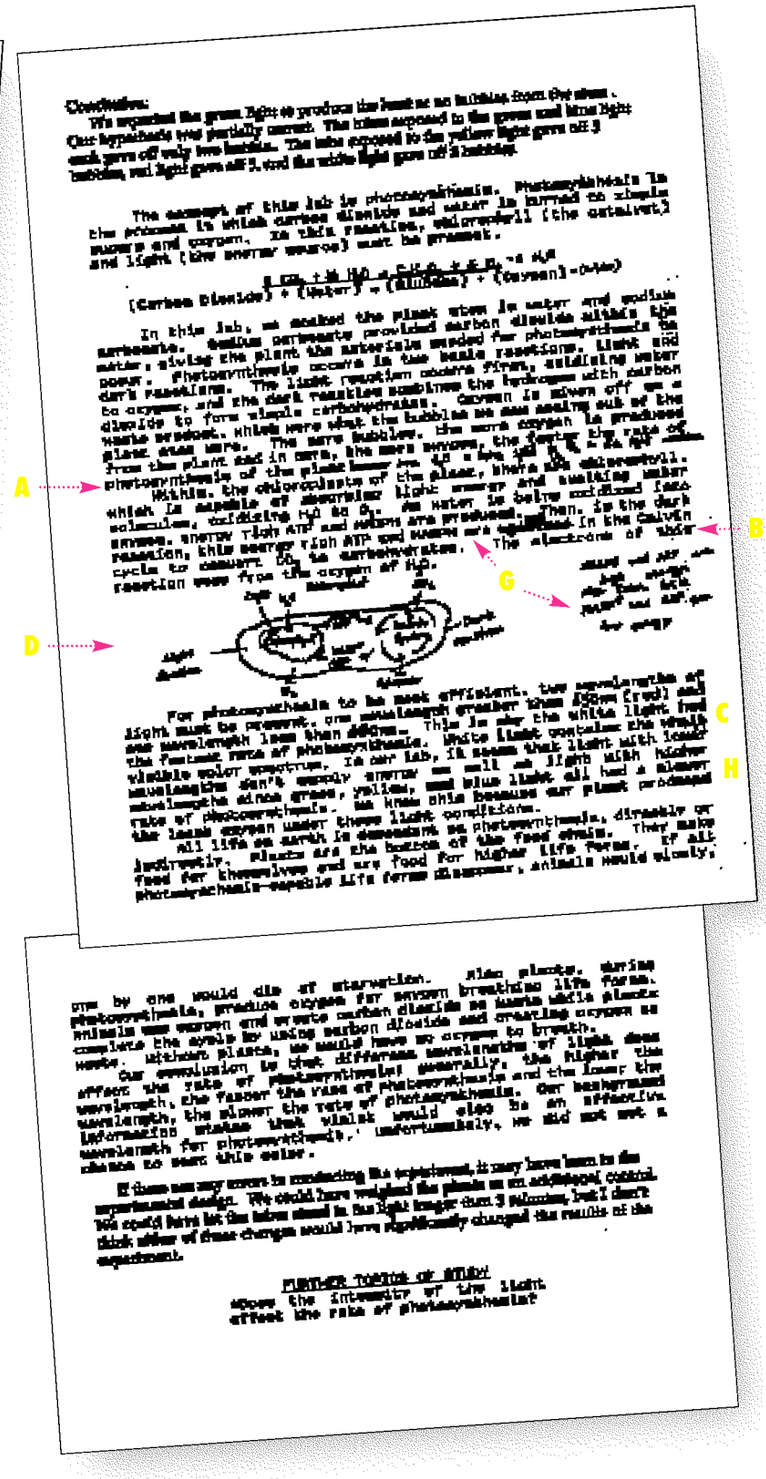
C Here and elsewhere, the work shows evidence of understanding the interactions of matter and energy through the discussion of wavelengths of light. An alternative or additional explanation for the high rate of photosynthesis for the white light is that all of the colored filters reduced the intensity of the light, meaning that fewer photons reached the leaf. There is no mention of the intensity of the light, but from the description of the procedure it is unlikely that this variable was not controlled.

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

- **S1 c Physical Sciences Concepts: Chemical reactions.**
- **S1 f Physical Sciences Concepts: Interactions of energy and matter.**
- **S2 a Life Sciences Concepts: The cell.**
- **S2 e Life Sciences Concepts: Matter, energy, and organization in living systems.**
- **S5 a Scientific Thinking: Frame questions to distinguish cause and effect; and identify or control variables.**
- **S6 a Scientific Tools and Technologies: Use technology and tools.**
- **S7 a Scientific Communication: Represent data in multiple ways.**

Photosynthesis





A B C D G H

S2 a Life Sciences Concepts: The student produces evidence that demonstrates understanding of the cell, such as cell structure and function relationships; regulation and biochemistry; and energy and photosynthesis.

D In describing what happens in the chloroplast of the cell, the work shows evidence of understanding the structure and function relationships inside the cell. The entire piece of work demonstrates understanding of photosynthesis.

S2 e Life Sciences Concepts: The student produces evidence that demonstrates understanding of matter, energy, and organization in living systems, such as matter and energy flow through different levels of organization; and environmental constraints.

E F The explanation of the flow of energy offers evidence of sophisticated understanding of the dynamic process whereby plants produce energy and other organisms rely on that energy for survival.

G The phrase "energy rich ATP and NADPH" appears above and adjacent to the cell drawing. It is true that NADPH has reducing power, but it is not an energy source, although ATP is.

S1 S2 S5 S6 S7

Photosynthesis

S5 a Scientific Thinking: The student frames questions to distinguish cause and effect; and identifies or controls variables in experimental and non-experimental research settings.

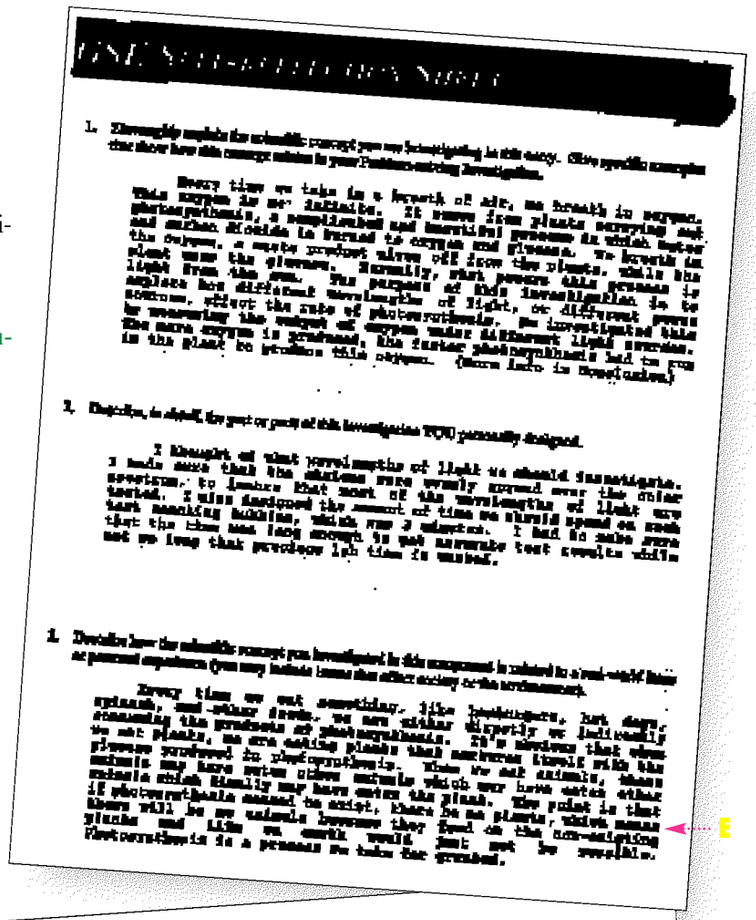
H Here and throughout, the work displays evidence of appropriate scientific thinking and use of experimental data to reach conclusions.

S6 a Scientific Tools and Technologies: The student uses technology and tools (such as traditional laboratory equipment, video, and computer aids) to observe and measure objects, organisms, and phenomena directly, indirectly, and remotely; and with appropriate consideration of accuracy and precision.

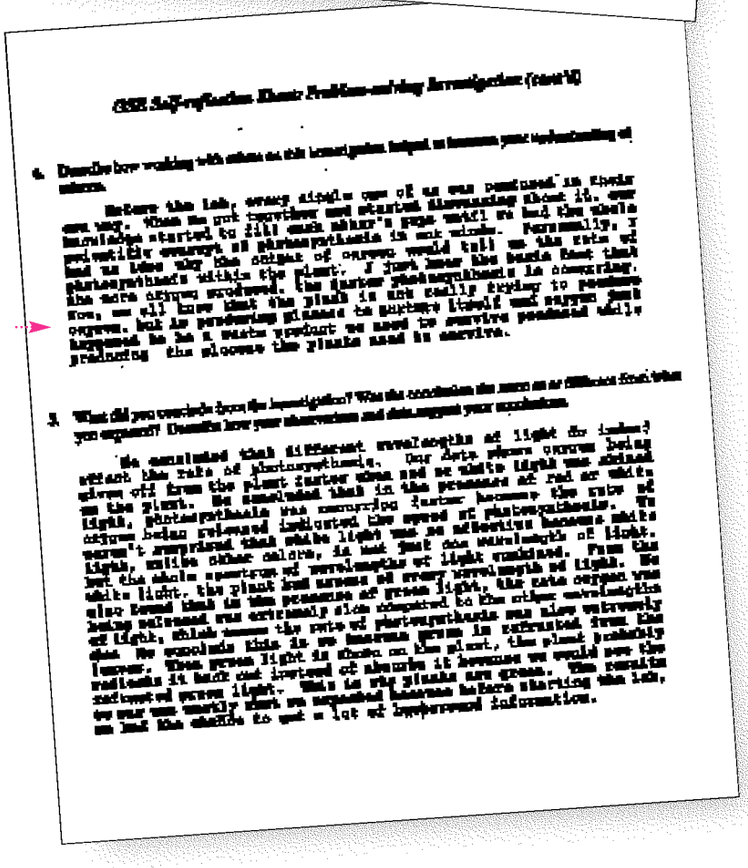
Appropriate tools and technologies are used effectively and procedures are executed thoughtfully.

S7 a Scientific Communication: The student represents data and results in multiple ways, such as numbers, tables, and graphs; drawings, diagrams, and artwork; technical and creative writing; and selects the most effective way to convey the scientific information.

Throughout the work, multiple representations (e.g., graphs, diagrams, and text) are effectively employed to enhance the communication of the scientific concepts.



E



F

Physical Sciences Concepts S1
Life Sciences Concepts S2
Earth and Space Sciences Concepts
Scientific Connections and Applications
Scientific Thinking S5
Scientific Tools and Technologies S6
Scientific Communication S7
Scientific Investigation

Work Sample & Commentary: *Bio-poem*

The task

Students in a high school biology class were asked to write a bio-poem about something they had learned. The biographical form required the students to include in their poems specific statements about characteristics, siblings, and needs.

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

This task resulted from a series of assignments which allowed the students to express the relationships between living things in creative ways.

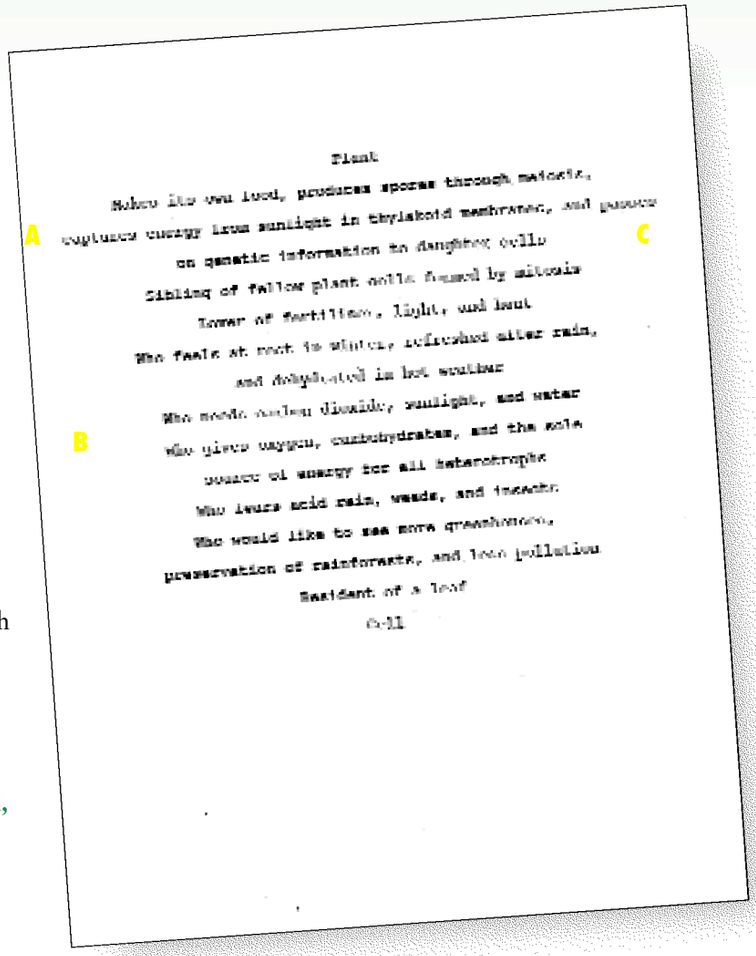
What the work shows

S2 a Life Sciences Concepts: The student produces evidence that demonstrates understanding of the cell, such as cell structure and function relationships;... and energy and photosynthesis.

A

S2 e Life Sciences Concepts: The student produces evidence that demonstrates understanding of matter, energy, and organization in living systems, such as matter and energy flow through different levels of organization....

B The student clearly identified the needs of plants and displayed understanding of the flow of energy between levels (plants to heterotrophs).



Plant

Makes its own food, produces spores through meiosis,

A captures energy from sunlight in thylakoid membranes, and passes C

on genetic information to daughter cells

Sibling of fellow plant cells formed by mitosis

Lover of fertilizer, light, and heat

Who feels at rest in sluicy, refreshed after rain,

and dehydrated in hot weather

Who needs carbon dioxide, sunlight, and water

B Who gives oxygen, carbohydrates, and the sole

source of energy for all heterotrophs

Who hates acid rain, weeds, and insects

Who would like to see more greenhouses,

preservation of rainforests, and less pollution

Resident of a leaf

C-11

S4 a Scientific Connections and Applications: The student produces evidence that demonstrates understanding of big ideas and unifying concepts, such as order and organization...; change and constancy....

The student demonstrated a complex understanding of biology throughout the work. By relating genetics and reproduction to the physiological needs of the plant and the products of photosynthesis, the student integrated many important ideas of science.

S7 d Scientific Communication: The student explains a scientific concept or procedure to other students.

C Using the bio-poem form, the student correctly explained several complex concepts related to plants. These concepts are complex to explain in simple language. In producing this type of poem the student demonstrated a deep understanding of the needs of, desirable conditions for, and energy flow through plants.

The use of "sibling" with respect to mitosis is a consequence of the literary form, not a misunderstanding of mitosis.

The quotations from the Science performance descriptions in this commentary are excerpted. The complete performance descriptions are shown on pages 82-85.

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

- **S2 a Life Sciences Concepts: The cell.**
- **S2 e Life Sciences Concepts: Matter, energy, and organization in living systems.**
- **S4 a Scientific Connections and Applications: Big ideas and unifying concepts.**
- **S7 d Scientific Communication: Explain a scientific concept or procedure to other students.**

Work Sample & Commentary: *Erosion on the Minnehaha Creek*

The quotations from the Science performance descriptions in this commentary are excerpted. The complete performance descriptions are shown on pages 82-85.

S6 makes explicit reference to using telecommunications to acquire and share information. A recent National Center on 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 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. New Standards partners have made a commitment to create the learning environments where students can develop the knowledge and skills delineated here.

The task

The National Student Research Center (NSRC) 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

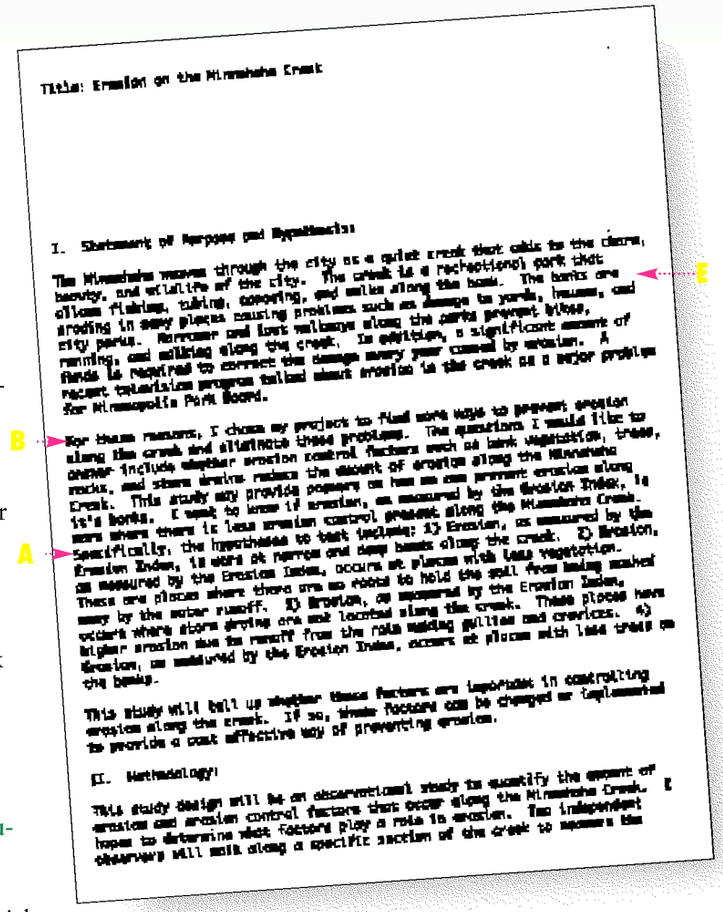
This sample of student work was produced under the following conditions:

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

What the work shows

S3 e Earth and Space Sciences Concepts: The student produces evidence that demonstrates understanding of natural resource management.

A The student produced a list of hypotheses which is really a list of explanations that give evidence of conceptual understanding of the mechanisms of erosion.



Title: Erosion on the Minnehaha Creek

I. Statement of Purpose and Hypothesis:

The Minnehaha weaves through the city as a quiet creek that adds to the charm, beauty, and vitality of the city. The creek is a recreational park that allows fishing, tubing, canoeing, and walks along the bank. The banks are eroding in many places causing problems such as damage to yards, houses, and city parks. Moreover and lost walkways along the parks prevent bikes, running, and walking along the creek. In addition, a significant amount of funds is required to correct the damage every year caused by erosion. A recent television program talked about erosion in the creek as a major problem for Minneapolis Park Board.

For these reasons, I chose my project to find more ways to prevent erosion along the creek and eliminate these problems. The questions I would like to answer include whether erosion control factors such as bank vegetation, trees, rocks, and storm drains reduce the amount of erosion along the Minnehaha Creek. This study may provide pamphlets on how an can prevent erosion along it's banks. I want to know if erosion, as measured by the Erosion Index, is more where there is less erosion control present along the Minnehaha Creek. Specifically, the hypotheses to test include: 1) Erosion, as measured by the Erosion Index, is more at narrow and deep bends along the creek. 2) Erosion, as measured by the Erosion Index, occurs at places with less vegetation. These are places where there are no roots to hold the soil from being washed away by the water runoff. 3) Erosion, as measured by the Erosion Index, occurs where storm drains are not located along the creek. These places have higher erosion due to runoff from the rain making gullies and crevices. 4) Erosion, as measured by the Erosion Index, occurs at places with less trees on the banks.

This study will tell us whether these factors are important in controlling erosion along the creek. If so, these factors can be changed or implemented to provide a cost effective way of preventing erosion.

II. Methodology:

This study design will be an observational study to quantify the amount of erosion and erosion control factors that occur along the Minnehaha Creek. I hope to determine what factors play a role in erosion. Two independent observers will walk along a specific section of the creek to measure the

The Student Researcher. Used by permission of the National Student Research Center, Dr. John I Swang, Mandeville Middle School, 2525 Soult Street, Mandeville, Louisiana 70448. 504-626-5980 or nsrcmms@aol.com.

S5 a Scientific Thinking: The student frames questions to distinguish cause and effect; and identifies or controls variables in experimental and non-experimental research settings.

B C The work shows that a number of steps were taken to measure erosion, although the Erosion Index that plays a critical role in the study is not explained. However, there is detailed evidence that most of the critical variables were identified and controlled.

S5 b Scientific Thinking: The student uses concepts from Standards 1 to 4 to explain a variety of observations and phenomena.

A

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

- S3 e Earth and Space Sciences Concepts: Natural resource management.
- S5 a Scientific Thinking: Frame questions to distinguish cause and effect; and identify or control variables.
- S5 b Scientific Thinking: Use concepts from Standards 1 to 4 to explain observations and phenomena.
- S5 c Scientific Thinking: Use evidence from reliable sources.
- S5 d Scientific Thinking: Distinguish between fact and opinion.
- S5 e Scientific Thinking: Identify problems and propose solutions.
- S5 f Scientific Thinking: Work individually and in teams.
- S6 a Scientific Tools and Technologies: Use technology and tools.

Erosion on the Minnehaha Creek

S5 c Scientific Thinking: The student uses evidence from reliable sources to develop descriptions [and] explanations…; and makes appropriate adjustments and improvements based on additional data or logical arguments.

D The explanation of erosion control factors and probability is strong evidence of this student using data from the field study to reach a defensible conclusion.

S5 d Scientific Thinking: The student…distinguishes between fact and opinion.

D The student explained the mathematical basis upon which he built his conclusion.

S5 e Scientific Thinking: The student identifies problems; proposes…solutions….

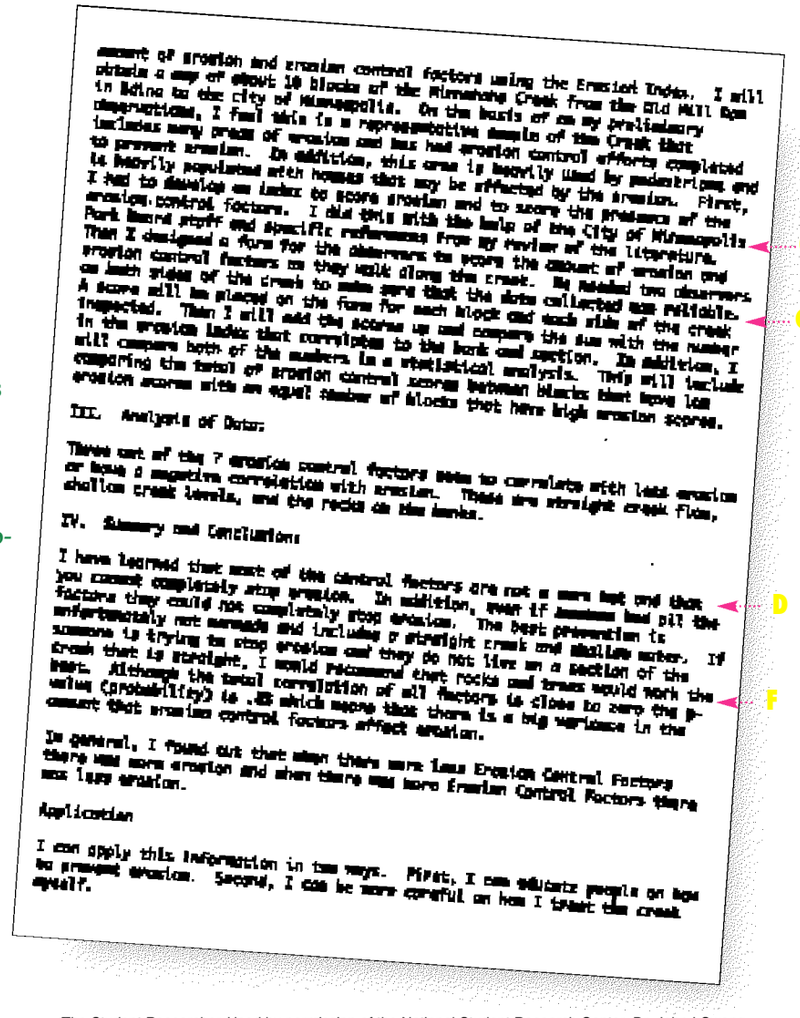
E F The work shows that the student clearly identified and defined the problem and used data to back up the conclusions, recommending a practice to solve part of the problem.

S5 f Scientific Thinking: The student works individually and in teams to collect and share information and ideas.

G

S6 a Scientific Tools and Technologies: The student uses technology and tools (such as traditional laboratory equipment…) to observe and measure objects, organisms, and phenomena, directly, indirectly, and remotely, with appropriate consideration of accuracy and precision.

The student displayed attention to accuracy and precision by including the following steps: deciding on a representative sample, developing an observation form with help from experts, training independent observers, and taking observations from both sides of the creek.



amount of erosion and erosion control factors using the Erosion Index. I will obtain a map of about 10 blocks of the Minnehaha Creek from the Old Mill Dam in Edina to the city of Minneapolis. On the basis of on my preliminary observations, I feel this is a representative sample of the Creek that includes many areas of erosion and has had erosion control efforts completed to prevent erosion. In addition, this area is heavily used by pedestrians and is heavily populated with homes that may be affected by the erosion. First, I had to develop an index to score erosion and to score the presence of the erosion control factors. I did this with the help of the City of Minneapolis Park Board staff and specific references from my review of the literature. Then I designed a form for the observers to score the amount of erosion and erosion control factors as they walk along the creek. My needed two observers on both sides of the creek to make sure that the data collected was reliable. A score will be placed on the form for each block and each side of the creek inspected. Then I will add the scores up and compare the sum with the number in the erosion index that corresponds to the bank and section. In addition, I will compare both of the numbers in a statistical analysis. This will include comparing the total of erosion control scores between blocks that have low erosion scores with an equal number of blocks that have high erosion scores.

III. Analysis of Data:

Three out of the 7 erosion control factors seem to correlate with less erosion or have a negative correlation with erosion. These are straight creek flow, shallow creek levels, and the rocks on the banks.

IV. Summary and Conclusion:

I have learned that most of the control factors are not a sure bet and that you cannot completely stop erosion. In addition, even if humans had all the factors they could not completely stop erosion. The best prevention is unfortunately not manmade and includes a straight creek and shallow water. If someone is trying to stop erosion and they do not live on a section of the creek that is straight, I would recommend that rocks and trees would work the best. Although the total correlation of all factors is close to zero the p-value (probability) is .85 which means that there is a big variance in the amount that erosion control factors affect erosion.

In general, I found out that when there were less Erosion Control Factors there was more erosion and when there was more Erosion Control Factors there was less erosion.

Application

I can apply this information in two ways. First, I can educate people on how to prevent erosion. Second, I can be more careful on how I treat the creek myself.

The Student Researcher. Used by permission of the National Student Research Center, Dr. John I Swang, Mandeville Middle School, 2525 Soult Street, Mandeville, Louisiana 70448. 504-626-5980 or nsrcmms@aol.com.

Work Sample & Commentary: *Are Oysters Safe to Eat?*

The task

The National Student Research Center (NSRC) 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.

The quotations from the Science performance descriptions in this commentary are excerpted. The complete performance descriptions are shown on pages 82-85.

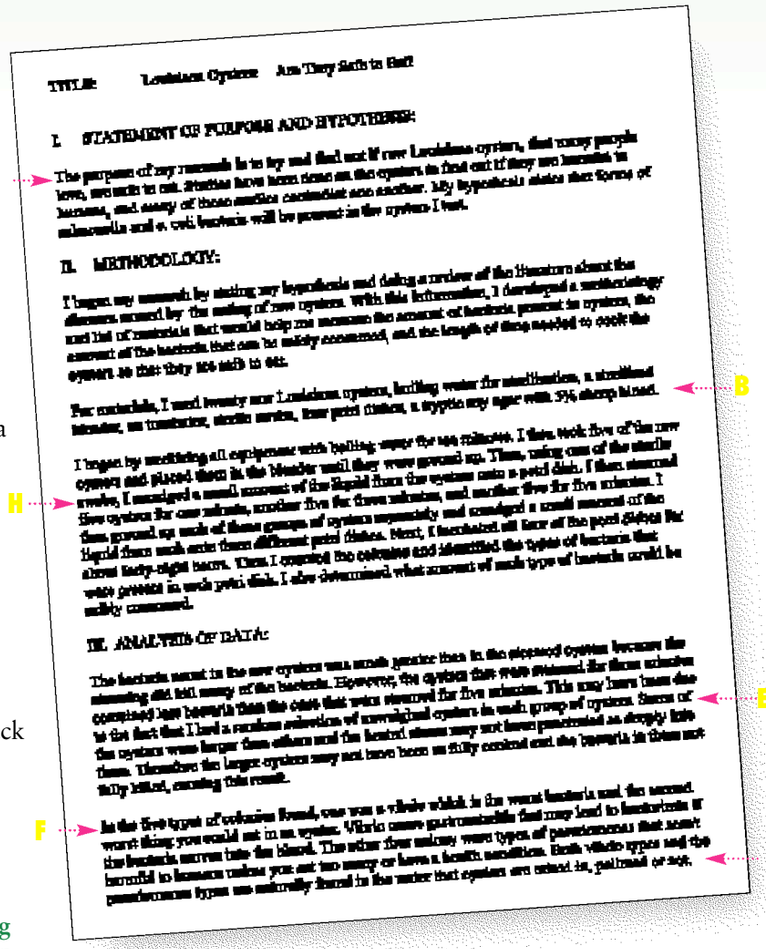
Circumstances of performance

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 d Life Sciences Concepts: The student produces evidence that demonstrates understanding of interdependence of organisms, such as…cooperation and competition among organisms in ecosystems….



TITLE: Louisiana Oysters Are They Safe to Eat?

I. STATEMENT OF PURPOSE AND HYPOTHESIS:

The purpose of my research is to try and find out if raw Louisiana oysters, that many people love, are safe to eat. Studies have been done on the oysters to find out if they are harmful to humans, and many of these studies contradict one another. My hypothesis states that forms of salmonella and e. coli bacteria will be present in the oysters I test.

II. METHODOLOGY:

I began my research by stating my hypothesis and doing a review of the literature about the diseases caused by the eating of raw oysters. With this information, I developed a methodology and list of materials that would help me measure the amount of bacteria present in oysters, the amount of the bacteria that can be safely consumed, and the length of time needed to cook the oysters so that they are safe to eat.

For materials, I used twenty raw Louisiana oysters, boiling water for sterilization, a sterilized blender, an incubator, sterile media, four petri dishes, a tryptic soy agar with 5% sheep blood.

I began by sterilizing all equipment with boiling water for ten minutes. I then took five of the raw oysters and placed them in the blender until they were pureed so. Then, using one of the sterile swabs, I sampled a small amount of the liquid from the oysters into a petri dish. I then streaked five oysters for one minute, another five for three minutes, and another five for five minutes. I then ground up each of these groups of oysters separately and sampled a small amount of the liquid from each onto three different petri dishes. Next, I incubated all four of the petri dishes for about forty-eight hours. Then I counted the colonies and identified the types of bacteria that were present in each petri dish. I also determined what amount of each type of bacteria could be safely consumed.

III. ANALYSIS OF DATA:

The bacteria count in the raw oysters was much greater than in the cooked oysters because the steaming did kill many of the bacteria. However, the oysters that were steamed for three minutes contained less bacteria than the ones that were steamed for five minutes. This may have been due to the fact that I had a random selection of unweighed oysters in each group of oysters. Some of the oysters were larger than others and the heated steam may not have penetrated as deeply into them. Therefore the larger oysters may not have been as fully cooked and the bacteria in them not fully killed, causing this result.

In the five types of colonies found, one was a vibrio which is the worst bacteria and the second worst thing you could eat in an oyster. Vibrio cause gastroenteritis that may lead to bacteriemia if the bacteria survive into the blood. The other four colony were types of pseudomonas that aren't harmful to humans unless you eat too many or have a health condition. Both vibrio types and the pseudomonas types are naturally found in the water that oysters are raised in, railroad or sea.

The Student Researcher. Used by permission of the National Student Research Center, Dr. John I Swang, Mandeville Middle School, 2525 Soult Street, Mandeville, Louisiana 70448. 504-626-5980 or nsrcmms@aol.com.

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

- **S2 d Life Sciences Concepts: Interdependence of organisms.**
- **S2 e Life Sciences Concepts: Matter, energy, and organization in living systems.**
- **S4 c Scientific Connections and Applications: Health, personal and environmental safety.**
- **S5 a Scientific Thinking: Frame questions to distinguish cause and effect; and identify or control variables.**
- **S5 b Scientific Thinking: Use concepts from Standards 1 to 4 to explain observations and phenomena.**
- **S5 c Scientific Thinking: Use evidence from reliable sources.**
- **S5 d Scientific Thinking: Distinguish between fact and opinion.**
- **S6 a Scientific Tools and Technologies: Use technology and tools.**
- **S6 d Scientific Tools and Technologies: Acquire information from multiple sources.**
- **S8 a Scientific Investigation: Controlled experiment.**

A Many animals and bacteria live in cooperation. The identification of bacterial forms that are naturally found in waters with oysters demonstrates understanding of this relationship.

B The use of agar as a growth medium and the identification of the need for sterile equipment provide evidence of understanding how bacteria grow as well as the importance of appropriate scientific procedures.

S2 e Life Sciences Concepts: The student produces evidence that demonstrates understanding of…organization in living systems, such as…environmental constraints.

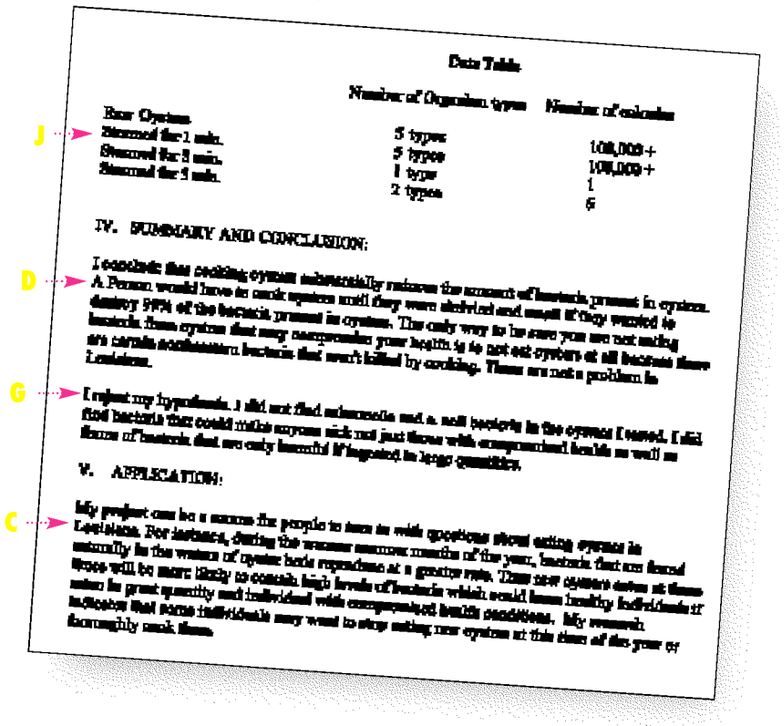
C The student related the rate of bacteria growth to temperature and season.

S4 c Scientific Connections and Applications: The student produces evidence that demonstrates understanding of health, such as…personal and environmental safety….

The student offered two types of warnings regarding bacteria and oysters.

Physical Sciences Concepts
Life Sciences Concepts S2
Earth and Space Sciences Concepts
Scientific Connections and Applications S4
Scientific Thinking S5
Scientific Tools and Technologies S6
Scientific Communication
Scientific Investigation S8

Are Oysters Safe to Eat?



Data Table

	Number of Organism types	Number of colonies
Raw Oysters		
Steamed for 1 min.	5 types	100,000+
Steamed for 3 min.	5 types	100,000+
Steamed for 5 min.	1 type	1
	2 types	6

IV. SUMMARY AND CONCLUSION:

I conclude that cooking oysters substantially reduces the amount of bacteria present in oysters. A Person would have to cook oysters until they were shriveled and small if they wanted to destroy 99% of the bacteria present in oysters. The only way to be sure you are not eating bacteria from oysters that may compromise your health is to not eat oysters at all because there are certain combination bacteria that aren't killed by cooking. These are not a problem in Louisiana.

I reject my hypothesis. I did not find salmonella and a. coli bacteria in the oysters I tested. I did find bacteria that could make anyone sick not just those with compromised health as well as those of bacteria that are only harmful if ingested in large quantities.

V. APPLICATION:

My project can be a source for people to turn to with questions about eating oysters in Louisiana. For instance, during the warmer summer months of the year, bacteria that are found naturally in the waters of oyster beds reproduce at a greater rate. Thus raw oysters eaten at these times will be more likely to contain high levels of bacteria which would mean healthy individuals if eaten in great quantity and individual with compromised health conditions. My research indicates that some individuals may want to stop eating raw oysters at this time of the year or thoroughly cook them.

The Student Researcher. Used by permission of the National Student Research Center, Dr. John I Swang, Mandeville Middle School, 2525 Soult Street, Mandeville, Louisiana 70448. 504-626-5980 or nsrcmms@aol.com.

D The first gives a method to reduce risk of bacterial infection significantly.

C The second indicates different levels of risk by season.

Both provide evidence of the quality of work expected at the high school level.

S5 a Scientific Thinking: The student frames questions to distinguish cause and effect; identifies and controls variables in experimental…research settings.

E The evaluation of data offers evidence that the student understood both variables she controlled and those she may have needed to control. The data analysis is focused and findings are used appropriately to answer the initial experimental question.

S5 b Scientific Thinking: The student uses concepts from Science Standards 1 to 4 to explain a variety of observations and phenomena.

F The student used concepts from **S2 d** here.

S5 c Scientific Thinking: The student uses evidence from reliable sources to develop descriptions, explanations…and makes appropriate adjustments and improvements based on additional data or logical arguments.

E G Discussion of unexpected results and critique of one's own procedures are the kind of scientific thinking that is required by this part of the standard.

S5 d Scientific Thinking: The student…distinguishes between fact and opinion.

G

S6 a Scientific Tools and Technologies: The student uses technology and tools (such as traditional laboratory equipment)…with appropriate consideration of accuracy and precision.

H The procedures are clearly reported, which makes it possible to find ample evidence that this part of the standard has been met. The use of sterile equipment was necessary for this investigation and shows appropriate attention to detail that is reflected in the reporting of the procedures.

S6 d Scientific Tools and Technologies: The student acquires information from multiple sources, such as print, the Internet…and experimentation.

The report is not explicit about how the bacteria were identified. Identifying bacteria is sophisticated work for a high school student. Assistance would have been appropriate (and should have been acknowledged).

S8 a Scientific Investigation: The student demonstrates scientific competence by completing a controlled experiment. A full investigation includes:

- Questions that can be studied using the resources available.

  I

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

  H

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

  H J

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

  J

- Recommendations, decisions, and conclusions based on evidence.

  C D

- Acknowledgment of references and contributions of others.
- Results that are communicated appropriately to audiences.

  C D

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

The student, as part of the NSRC format, loaded this work up onto the Internet for peer review. It is not stated whether this review informed the final report.

Work Sample & Commentary: *Interview With Aspirin*

The quotations from the Science performance descriptions in this commentary are excerpted. The complete performance descriptions are shown on pages 82-85.

The task

Students were asked to write a report on the benefits and risks of common medications. This student compared three medications: aspirin, acetaminophen, and ibuprofen.

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

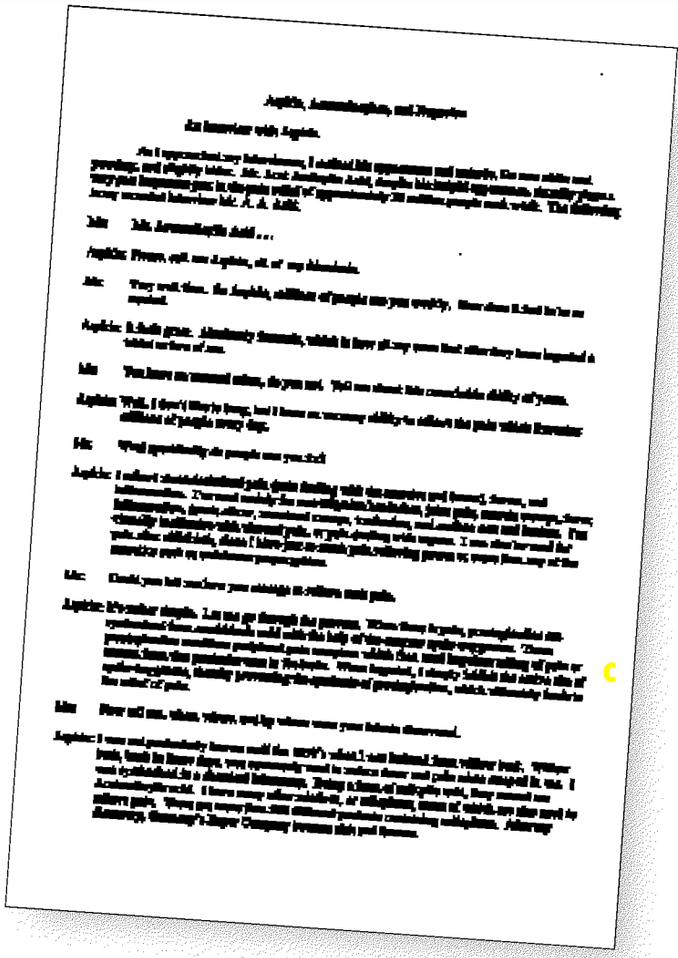
What the work shows

S2 f Life Sciences Concepts: The student produces evidence that demonstrates understanding of behavior of organisms, such as nervous system regulation….

A The discussion of the effects of aspirin demonstrates understanding of homeostatic mechanisms on clotting and bleeding.

B The connection between overdose and effects on the central nervous system clearly shows conceptual understanding of system control, maintenance, and the benefits and risks of medication.

C The understanding that human systems are regulated by the production of specific chemicals is consistently demonstrated throughout this work.



C

S4 c Scientific Connections and Applications: The student produces evidence that demonstrates understanding of health, such as…disease…; personal and environmental safety….

D E Understanding of health is evident throughout this piece. For example, the distinction between curing ailments, reducing pain and fever, and the summary of the three medications shows understanding as well as detail.

S7 a Scientific Communication: The student represents data and results in multiple ways, such as…technical and creative writing.

The interview format is a creative way to provide a great amount of detail. This form requires the student to have a great deal of background knowledge and adequate understanding of the underlying concepts in order to present the information accurately.

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

- S2 f Life Sciences Concepts: Behavior of organisms.
- S4 c Scientific Connections and Applications: Health.
- S7 a Scientific Communication: Represent data in multiple ways.
- S7 b Scientific Communication: Argue from evidence.
- S7 d Scientific Communication: Explain a scientific concept or procedure to other students.
- S7 e Scientific Communication: Communicate in a form suited to the purpose and audience.
- E2 a Writing: Produce a report.

Interview With Aspirin

S7 b Scientific Communication: The student argues from evidence, such as data produced through his or her own experimentation or...by others.

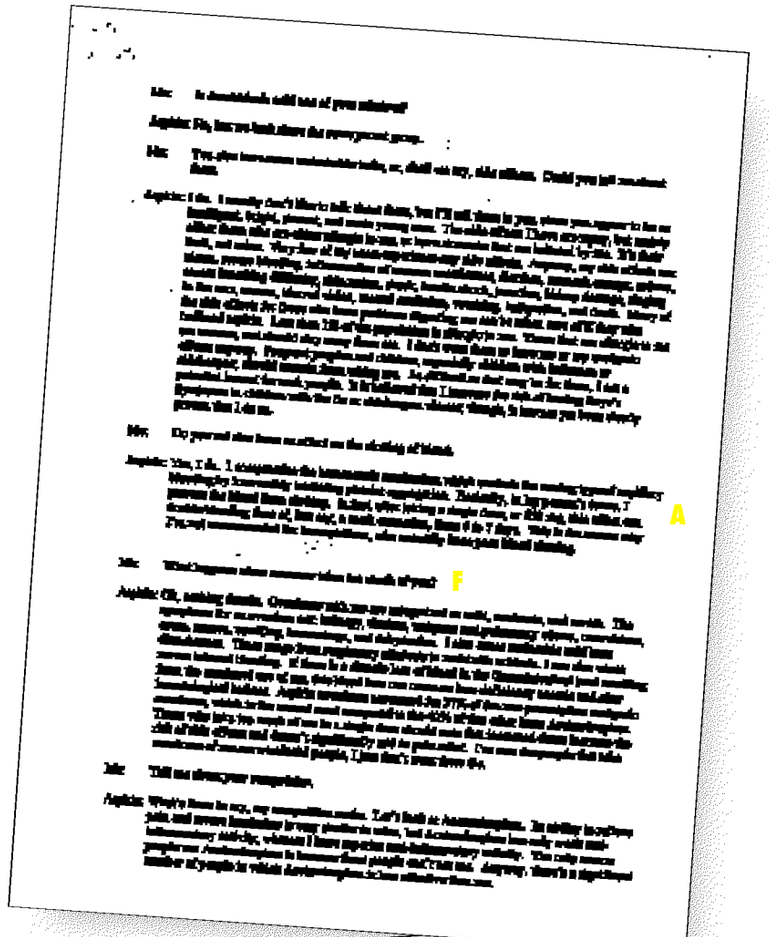
The work covers a range of information from uses to benefits and risks, giving a complete explanation and summary from varied sources. It does not consider the biases of these sources of information and this (apparently) uncritical acceptance of the information is a shortcoming of the piece.

S7 d Scientific Communication: The student explains a scientific concept or procedure to other students.

F The construction of the interview questions frames the topic in a way that allows an explanation of each medication to be given in depth. Careful attention to detail in the discussion of the effects of overdoses and how aspirin chemically blocks pain provides the clarity necessary to illustrate this part of S7 .

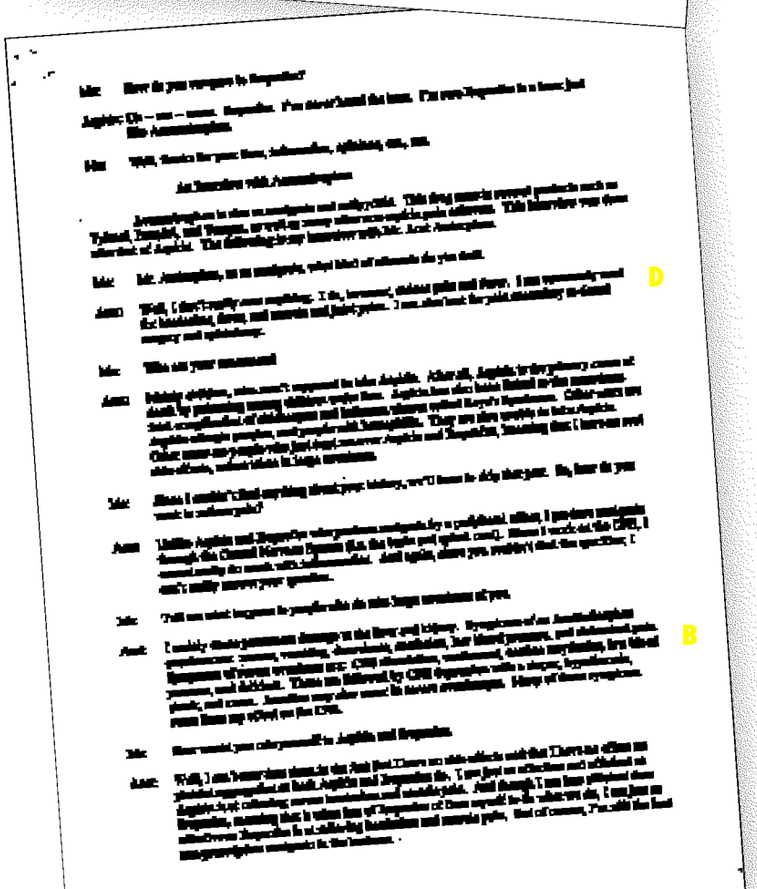
S7 e Scientific Communication: The student communicates in a form suited to the purpose and the audience....

The format for the comparison, an interview with each of the pain relievers, is an effective way of presenting information that could be tedious to read if presented in a traditional report. However, the format limits the depth of conceptual understanding that is demonstrated.



A

F



D

B

Interview With Aspirin

E2 a Writing: The student produces a report that:

- engages the reader by establishing a context, creating a persona, and otherwise developing reader interest;
- develops a controlling idea that conveys a perspective on the subject;
- creates an organizing structure appropriate to purpose, audience, and context;
- includes appropriate facts and details;
- excludes extraneous and inappropriate information;
- uses a range of appropriate strategies, such as providing facts and details, describing or analyzing the subject, narrating a relevant anecdote, comparing and contrasting, naming, explaining benefits or limitations, demonstrating claims or assertions, and providing a scenario to illustrate;
- provides a sense of closure to the writing.

The work is presented within the controlling idea of a series of interviews.

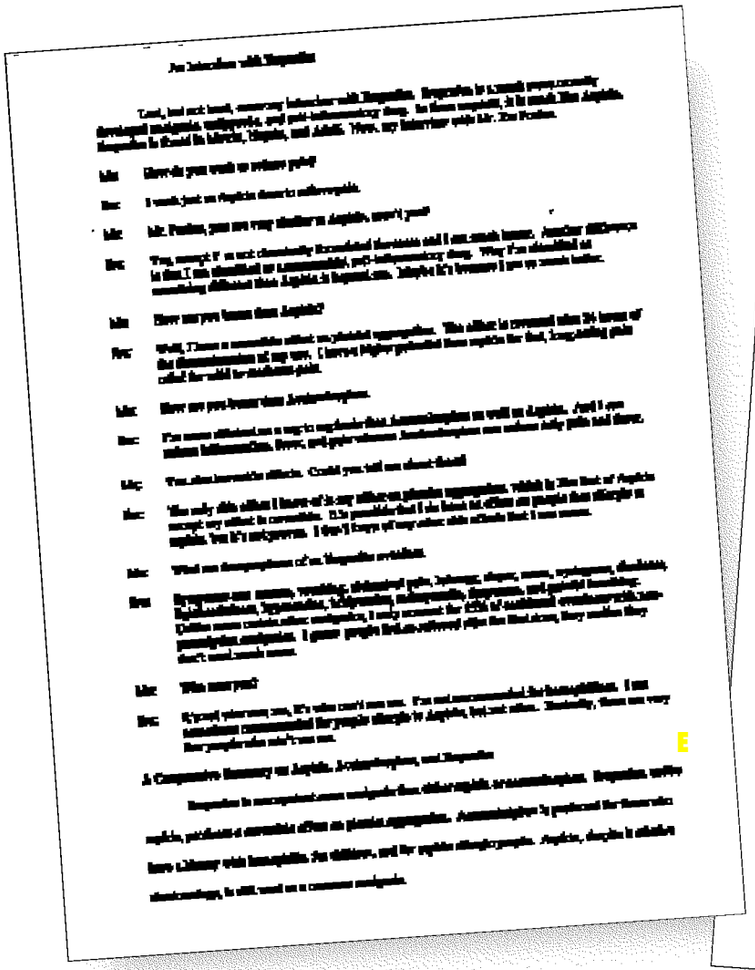
The reader's interest is engaged through the establishment of three independent personas in a familiar "interview-with-a-celebrity" format.

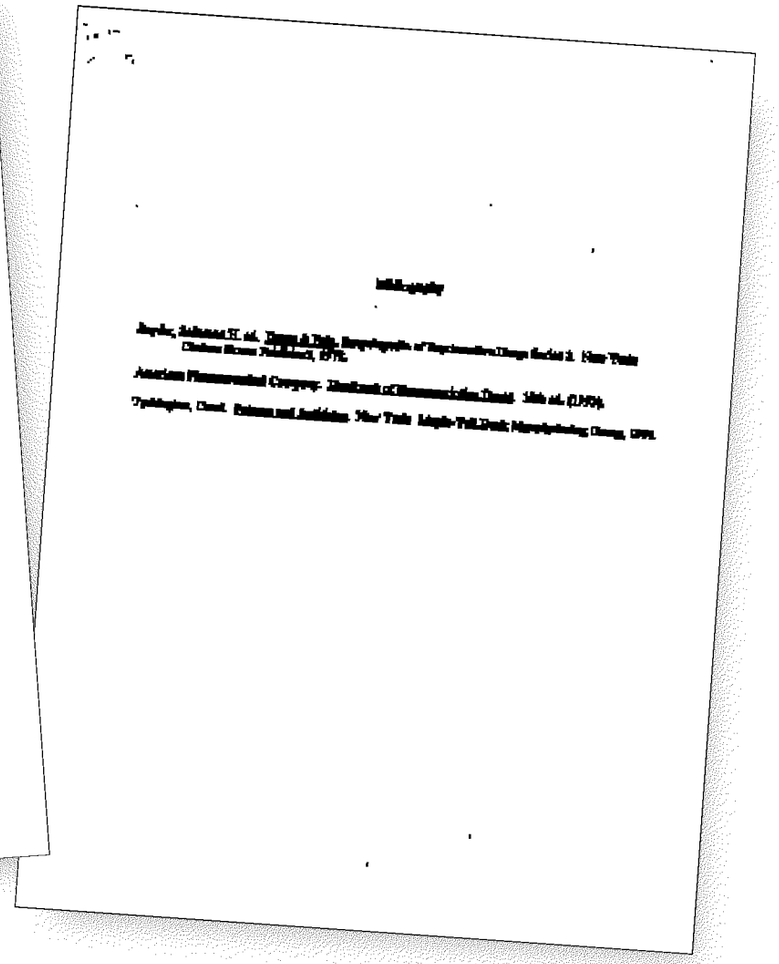
C The organizing structure of the interviews allowed the student to convey information to his teacher and fellow students in an interesting and memorable fashion.

The three sections, for the most part, include parallel facts and details, allowing for a useful comparison among the three pain relievers.

The student employed the strategy of communicating facts and details within a narrative.

E The student provided a clear sense of closure by summarizing the benefits and risks of three common medications.





Work Sample & Commentary: *A Geographical Report*

The task

Students were assigned to write a report for science class using at least five sources, only two of which could be encyclopedias. They were encouraged to include clarifications or illustrations of key points and a complete bibliography.

Circumstances of performance

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

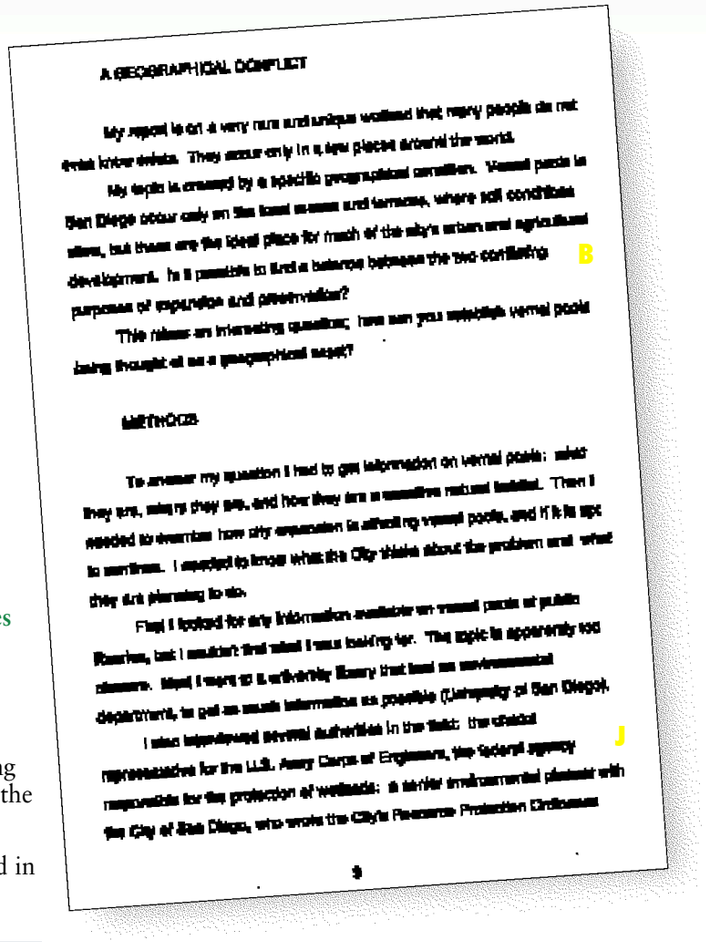
alone	in a group
in class	as homework
with teacher feedback	with peer feedback
timed	opportunity for revision

What the work shows

S2 d Life Sciences Concepts: The student produces evidence that demonstrates understanding of the interdependence of organisms, such as…cooperation and competition among organisms in ecosystems; and human effects on the environment.

A The student pointed out the necessity of having rabbits at the vernal pools to eat and then spread the seeds of digested plants.

B The pressure placed on this ecosystem is noted in the initial question.



A GEOGRAPHICAL CONFLICT

My report is on a very rare and unique wetland that many people do not even know exists. They occur only in a few places around the world.

My topic is caused by a specific geographical condition. Vernal pools in San Diego occur only on the local mesas and terraces, where soil conditions allow, but these are the ideal place for much of the city's urban and agricultural development. Is it possible to find a balance between the two conflicting purposes of expansion and preservation? B

This raises an interesting question; how can you sensibly vernal pools being thought of as a geographical asset?

METHODS

To answer my question I had to get information on vernal pools: what they are, where they are, and how they are a sensitive natural habitat. Then I needed to examine how city expansion is affecting vernal pools, and if it is spot to continue. I wanted to know what the City thinks about the problem and what they are planning to do.

First I looked for any information available on vernal pools at public libraries, but I couldn't find what I was looking for. The topic is apparently too obscure. Next I went to a university library that had an environmental department, to get as much information as possible (University of San Diego).

I also interviewed several authorities in the field: the district representative for the U.S. Army Corps of Engineers, the federal agency responsible for the protection of wetlands; a similar environmental planner with the City of San Diego, who works the City's Resource Protection Ordinance J

9

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

- S2 d Life Sciences Concepts: Interdependence of organisms.
- S3 e Earth and Space Sciences Concepts: Natural resource management.
- S5 a Scientific Thinking: Frame questions to distinguish cause and effect.
- S5 b Scientific Thinking: Use concepts from Standards 1 to 4 to explain observations and phenomena.
- S5 c Scientific Thinking: Use evidence from reliable sources.
- S5 d Scientific Thinking: Consider alternative explanations.
- S7 a Scientific Communication: Represent data and results in multiple ways.
- S7 d Scientific Communication: Explain a scientific concept to other students.
- S7 e Scientific Communication: Communicate in a form suited to the purpose and audience.
- S8 c Scientific Investigation: Design.
- S8 d Scientific Investigation: Secondary research.

C The student offered further explanation of human impact on this ecosystem.

D E The student made suggestions to minimize the damage caused by development.

S3 e Earth and Space Sciences Concepts: The student produces evidence that demonstrates understanding of…natural resource management.

F G H The student constructed a strong argument for the protection of the vernal pools.

S5 a Scientific Thinking: The student frames questions to distinguish cause and effect….

B

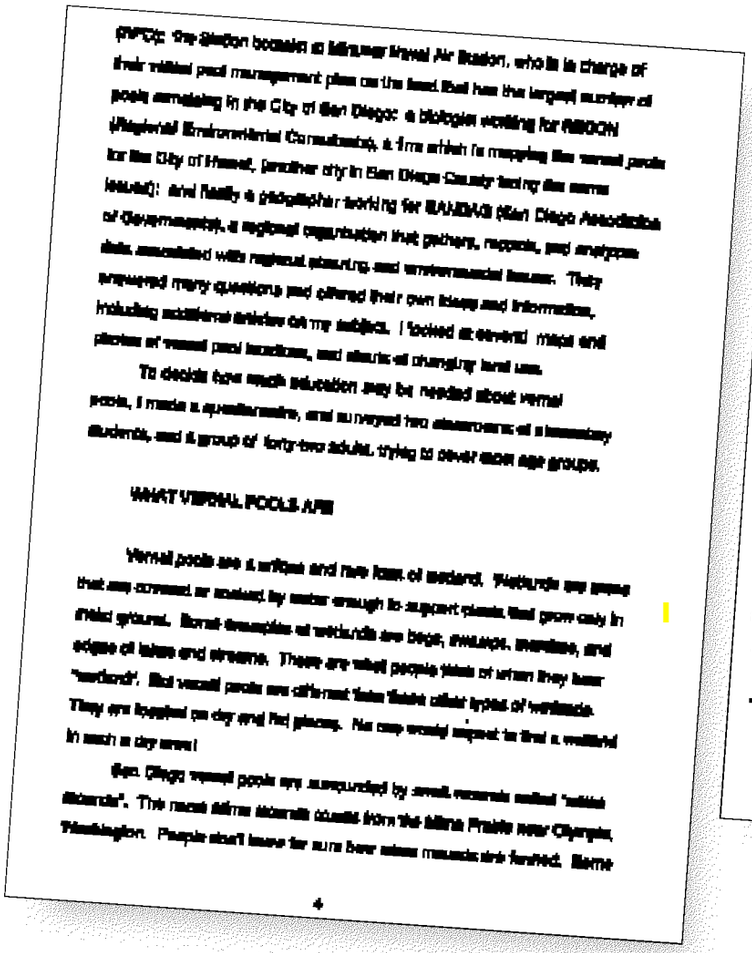
S5 b Scientific Thinking: The student uses concepts from Science Standards 1 to 4 to explain a variety of observations and phenomena.

I The student used conceptual information here and throughout the work to explain the pools and to develop the view of these wetlands as a geographical asset.

The quotations from the Science performance descriptions in this commentary are excerpted. The complete performance descriptions are shown on pages 82-85.

The standards for middle school are set at a level of performance approximately equivalent to the end of eighth grade and for high school at the end of tenth grade. It is expected that some students might achieve these levels earlier and others later than these grades. It is the expected quality of work rather than the age or grade of the student that govern the selection of work to illustrate the standards. This work sample appears in *New Standards Performance Standards* Volume 2 to illustrate a standard-setting performance for writing a report for the English Language Arts standards at the middle school level. The conceptual understanding in science, however, is at the level expected for high school. Thus, we have included the piece again here despite the age or grade of the student who produced it.

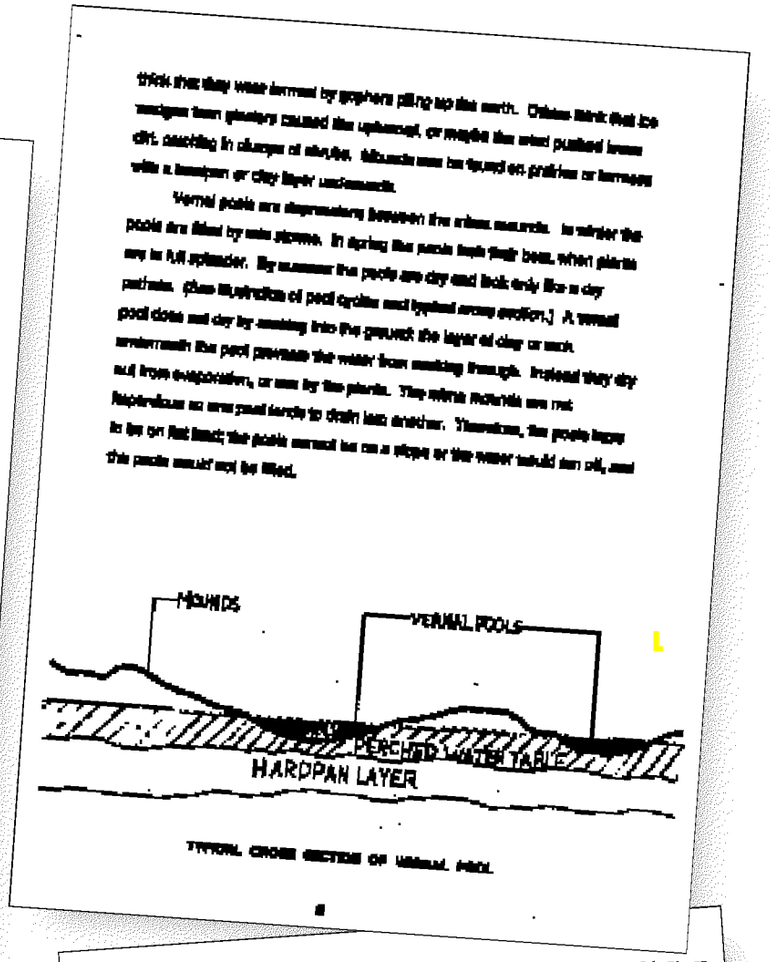
A Geographical Report



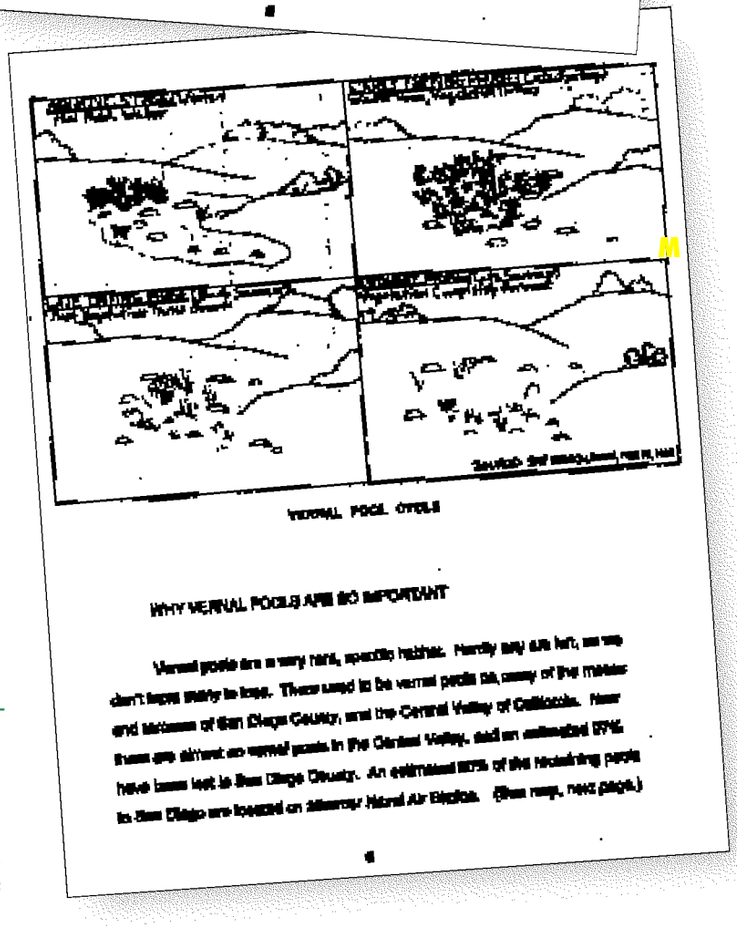
WHAT VERNAL POOLS ARE

Vernal pools are a unique and rare type of wetland. Wetlands are areas that are covered or soaked by water enough to support plants that grow only in moist ground. Some examples of wetlands are bogs, swamps, marshes, and edges of lakes and streams. These are what people think of when they hear "wetland". But vernal pools are different from these other types of wetlands. They are located on dry and flat places. No one would expect to find a wetland in such a dry area!

San Diego vernal pools are surrounded by small mounds called "mima mounds". The name mima mounds comes from the Mima Prairie near Olympia, Washington. People don't know for sure how mima mounds are formed. Some



TYPICAL CROSS SECTION OF VERNAL POOL



TYPICAL POOL CYCLE

WHY VERNAL POOLS ARE SO IMPORTANT

Vernal pools are a very rare, specific habitat. Hardly any are left, so we don't have many to lose. There used to be vernal pools in many of the valleys and mesas of San Diego County, and the Central Valley of California. Now there are almost no vernal pools in the Central Valley, and an estimated 90% have been lost in San Diego County. An estimated 85% of the remaining pools in San Diego are located on Miramar Naval Air Station. (See map, next page.)

Physical Sciences Concepts
Life Sciences Concepts S2
Earth and Space Sciences Concepts S3
Scientific Connections and Applications
Scientific Thinking S5
Scientific Tools and Technologies
Scientific Communication S7
Scientific Investigation S8

S5 c Scientific Thinking: The student uses evidence from reliable sources to develop descriptions, explanations….

J K The student did not limit the work to what could be found at public libraries, but conducted interviews and a significant literature search to find the information needed.

S5 d Scientific Thinking: The student proposes, recognizes, analyzes, considers, and critiques alternative explanations; and distinguishes between fact and opinion.

K Consideration of alternative explanations or solutions is not evident in the text itself, but the depth and breadth of the bibliography suggest that the work took into account a diversity of ideas.

S7 a Scientific Communication: The student represents data and results in multiple ways, such as…graphs; drawings, diagrams, and artwork; technical...writing; and selects the most effective way to convey the scientific information.

The student used a combination of clear writing, diagrams, and references to other portions of the work to clearly communicate the structure and cycles of these pools.

L M N The diagrams are particularly effective.

A Geographical Report

S7 d Scientific Communication: The student explains a scientific concept…to other students.

L M These drawings, which explain the cross-section of a vernal pool and the vernal pool cycle, are especially good examples.

S7 e Scientific Communication: The student communicates in a form suited to the purpose and the audience….

Throughout the work, the text succeeds in explaining and persuading.

S8 c Scientific Investigation: The student demonstrates scientific competence by completing a design project.

S8 d Scientific Investigation: The student demonstrates scientific competence by completing a secondary research project.

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 analyzed using skills expected at this grade level (see also Mathematics Standard 4).

Throughout the work, the student left a clear path for another student to follow in order to replicate the investigation or verify the conclusions.

- 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.

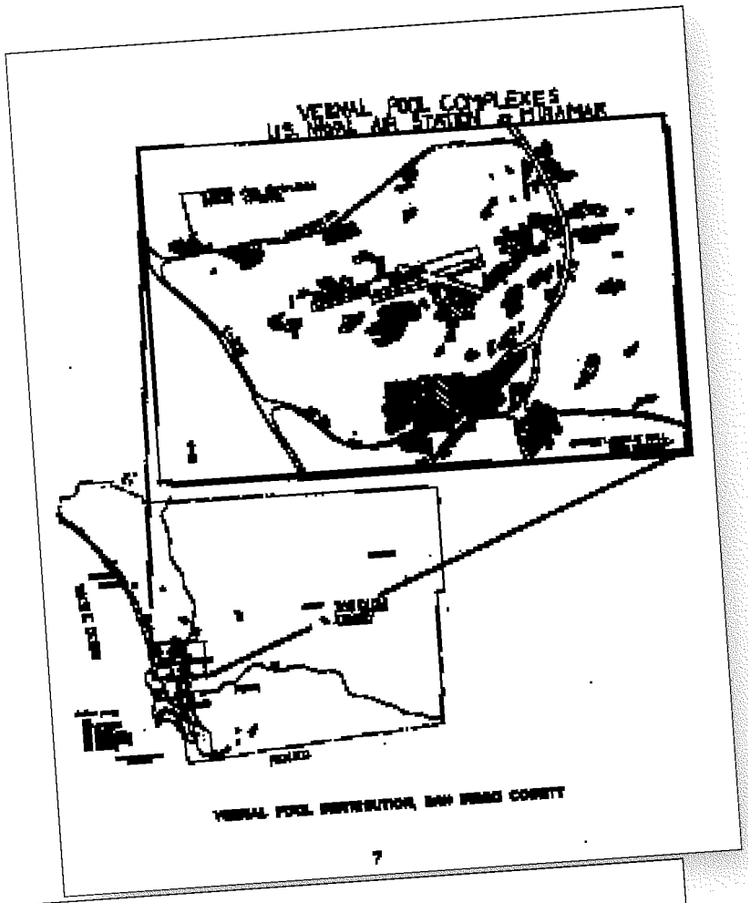
E N The student argued from evidence to draw conclusions and make recommendations in a way that is focused and coherent.

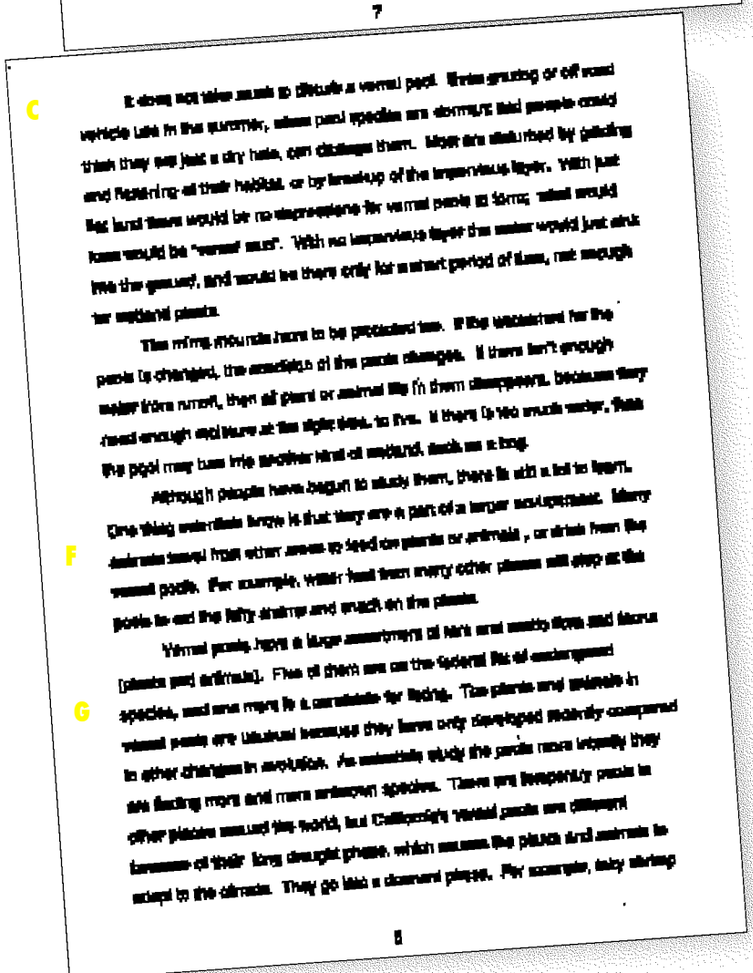
- Acknowledgment of references and contributions of others.

O

- Results that are communicated appropriately to audiences.
- Reflection and defense of conclusions and recommendations from other sources and peer review.

Peer review is not included in the work. However, the extensive communication with experts shows that the conclusions were informed, in part, with the help of iterative external review.





C It does not take much to disturb a vernal pool. Times grading or off road vehicle use in the summer, when pool species are dormant, had people could think they say just a dry hole, can damage them. Most are disturbed by polluting and fragmenting of their habitat, or by breakup of the impervious layer. With just flat land there would be no depressions for vernal pools to form; what would have would be "vernal mud". With no impervious layer the water would just sink into the ground, and would be there only for a short period of time, not enough for wetland plants.

The rolling mounds have to be protected too. If the watershed for the pools is changed, the condition of the pools changes. If there isn't enough water from runoff, then all plant or animal life in them disappears, because they need enough moisture at the right time to live. If there is too much water, then the pool may turn into another kind of wetland, such as a bog.

Although people have begun to study them, there is still a lot to learn.

F One thing scientists know is that they are a part of a larger ecosystem. Many animals travel from other areas to feed on plants or animals, or drink from the vernal pools. For example, water fowl from many other places will stop at the pools to eat the fairy shrimp and snack on the plants.

G Vernal pools have a large assortment of rare and exotic flora and fauna (plants and animals). Five of them are on the federal list of endangered species, and one more is a candidate for listing. The plants and animals in vernal pools are unusual because they have only developed recently compared to other changes in evolution. As scientists study the pools more intently they are finding more and more unknown species. There are temporary pools in other places around the world, but California's vernal pools are different because of their long drought phase, which causes the plants and animals to adapt to the climate. They go into a dormant phase. For example, fairy shrimp

8

A Geographical Report

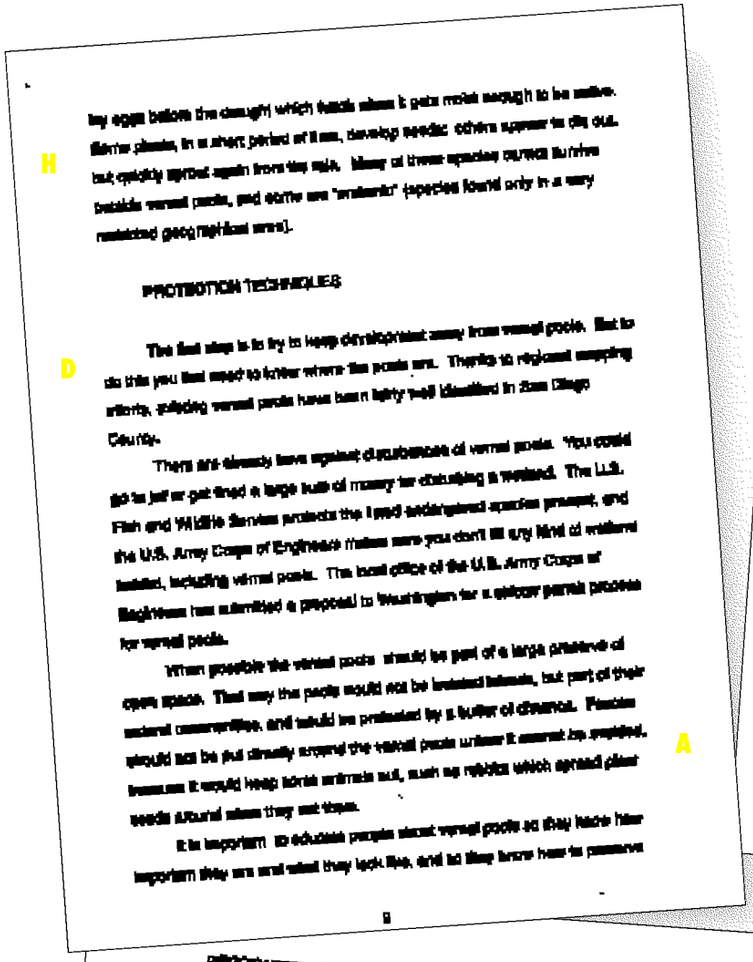
H

D

A

E

N



PROTECTION TECHNIQUES

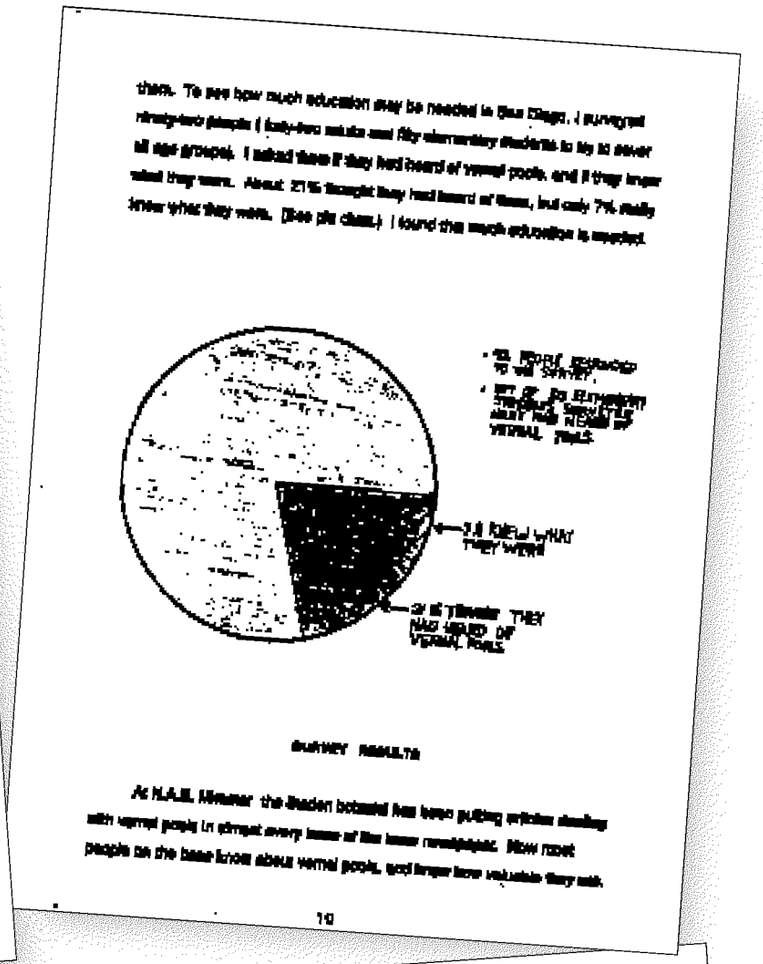
The first step is to try to keep development away from vernal pools. Not to do this you first need to know where the pools are. Thanks to regional mapping efforts, existing vernal pools have been fairly well identified in San Diego County.

There are already laws against disturbance of vernal pools. You could go to jail or get fined a large sum of money for disturbing a vernal. The U.S. Fish and Wildlife Service protects the listed endangered species present, and the U.S. Army Corps of Engineers makes sure you don't do any kind of wetland habitat, including vernal pools. The local office of the U.S. Army Corps of Engineers has submitted a proposal to Washington for a special permit process for vernal pools.

When possible the vernal pools should be part of a large preserve of open space. That way the pools would not be isolated islands, but part of their natural communities, and would be protected by a buffer of distance. Fences would not be put directly around the vernal pools unless it seemed to protect, because it would keep some animals out, such as rabbits which spread plant seeds around when they eat them.

It is important to educate people about vernal pools so they know how important they are and what they look like, and so they know how to preserve

9



them. To see how much education may be needed in San Diego, I surveyed nineteen people (sixty-two adults and fifty elementary students to try to cover all age groups). I asked them if they had heard of vernal pools, and if they knew what they were. About 21% thought they had heard of them, but only 7% really knew what they were. (See pie chart.) I found this much education is needed.

SURVEY RESULTS

At H.A.B. Meadow the Boden botanist has been putting articles dealing with vernal pools in almost every issue of the local newspaper. Now most people on the base know about vernal pools, and know how valuable they are.

10

RECOMMENDATIONS AND ASSET

Education is a key to preserving vernal pools. Vernal pools are very unique and we do not have many of them. Making new ones does not work. Studies done at the University of California, Santa Barbara, have shown that after five years their complexity goes down.

First, vernal pools must be protected. There could be different ranges of accessibility, from remote (available to research only), somewhat accessible (good for guided personal study), to readily accessible (which may have to be protected by fencing or supervision). The most accessible ones would be a great educational opportunity for the general public. The pools closer to developments could be developed into nature centers, with raised boardwalks to protect the habitat, as is done over the hot springs in Yellowstone. (See illustration.)

CROSS SECTION OF POSSIBLE NATURE CENTER

11

Interpretive signs and displays could provide information. Being very unique, vernal pools would make interesting learning centers. People would learn how the plants and animals adapt to the seasonal changes. This would teach people the importance of vernal pools, how complex they are, how to identify them, and how to preserve them when wet or dry. A park in the Sacramento area has an adjacent vernal pool with hiking trails around it; and it seems to work there because the people there know how important and delicate it is.

Ecotourism, a popular concept now, would be another idea. San Diego is a place where tourists already come. The city climate and geography that brings people here is what created vernal pools. Ecotourism would be easy to add to the other attractions, and would indirectly benefit the city. A tour company might be authorized to place advertisements to bring people to learn the importance of vernal pools and their ecosystem. Away from people outside San Diego forgetting about vernal pools and concerned about their well-being, there would be widespread support for vernal pool protection.

CONCLUSION

The problem of endangering vernal pools will not go away, because the City will need more land to develop. However, vernal pools remain a rare and unique wetland, and need protection. Even though there are laws made to protect them, pools are still being lost. Education is needed. Widespread education showing how important vernal pools are, and how rare they are to obtain, will create widespread support for protection.

A balance between expansion and preservation will not come easily, but if the public views vernal pools as a geographical asset, the balance will give toward long-term vernal pool preservation.

Physical Sciences Concepts
Life Sciences Concepts S2
Earth and Space Sciences Concepts S3
Scientific Connections and Applications
Scientific Thinking S5
Scientific Tools and Technologies
Scientific Communication S7
Scientific Investigation S8

A Geographical Report

K

BIBLIOGRAPHY

Ashworth, William. "Vernal Pool". The Encyclopedia of Environmental Studies, 1991, p. 418.

Barbour, Michael G. and Major, Jack, ed. Terrestrial Vegetation of California, New York: John Wiley and Sons, 1977.

Bauldi, Yvonne. "California's Ephemeral Vernal Pools May be a Good Model for Spectator". BioScience, vol. 44 no. 6, June 1994, pp. 364-366.

City of San Diego Mass Mound-Vernal Pool Guidelines. July 30, 1992.

City of San Diego Municipal Code, Section 101.0462. "Wetlands Protection Ordinance".

Franklin, Jerry F. and Dyrness, C.T., "Natural Vegetation of Oregon and Washington". Portland, Oregon: Pacific Northwest Forest and Range Experiment Station (General Technical Report PNW-8), 1973.

Hutchison, Steven M. "A Phenomenon of Spring: Vernal Pools". Environmental Southwest, no. 480, Winter 1978.

Jenny, Hans. "The Soil Resource: Origin and Behavior". New York: Springer, 1980, pp. 238-239, 380-382, 398.

Martin, Glen. "Spring Fever". Discover, vol. 11 no. 3, March 1990, pp. 70-74.

Clement, Neil. "Dwindling Treasure: Unique Creeps / Marsh Habitats Vanishing Fast". San Diego Union, February 19, 1989.

"Regulatory Permit Program". U.S. Army Corps of Engineers, Los Angeles District [ER. PAM 1130-2-1], Nov., 1993.

SANDAG. "A Look at San Diego's Future". INFO, January-February, 1994.

SANDAG. "Land Use in the San Diego Region". INFO, January-February, 1993.

White, Scott D. "Vernal Pools in the San Jacinto Valley". Fremontia, vol. 22 no. 4, October 1994, pp. 17-19.

Zedler, Paul H. "The Ecology of Southern California Vernal Pools: A Community Profile". U.S.D.I., Fish and Wildlife Service, Washington D.C. [Biological Report 85 (7.11)], May 1987.

13

INTERVIEWS

_____ Senior research analyst. SANDAG (San Diego Association of Governments). January 8, 1995.

_____ Station botanist. U.S. Naval Air Station, Miramar. November 21, 1994.

_____ Director of biological services. RECON (Regional Environmental Consultants). December 8, 1994.

_____ Biologist. U.S. Army Corps of Engineers, San Diego Field Office. November 23, 1994.

_____ Senior Planner. City of San Diego, Environmental Services Department. December 7, 1994.

O

ACKNOWLEDGMENTS

First I would like to thank the library at the University of San Diego for supplying me with information and help. I would also like to thank all the people I interviewed, especially _____ for supplying me with two slides of a vernal pool. Also my uncle, _____, Department of Geography, Indiana University-Purdue University, Indianapolis, for information on mima mounds. And _____, Biology Department, University of San Diego, and Ms. _____, RECON, for recommending people to interview. I would like to thank my former sixth grade teacher, and _____ Elementary School, for letting their classes take my survey.

Work Sample & Commentary: *Compost*

The task

Students were asked to design and conduct an experimental project that would improve the environment at their high school. The assignment, given to students in an environmental science class, followed a unit on the chemistry and biology of ground and water pollution.

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

The quotations from the Science performance descriptions in this commentary are excerpted. The complete performance descriptions are shown on pages 82-85.

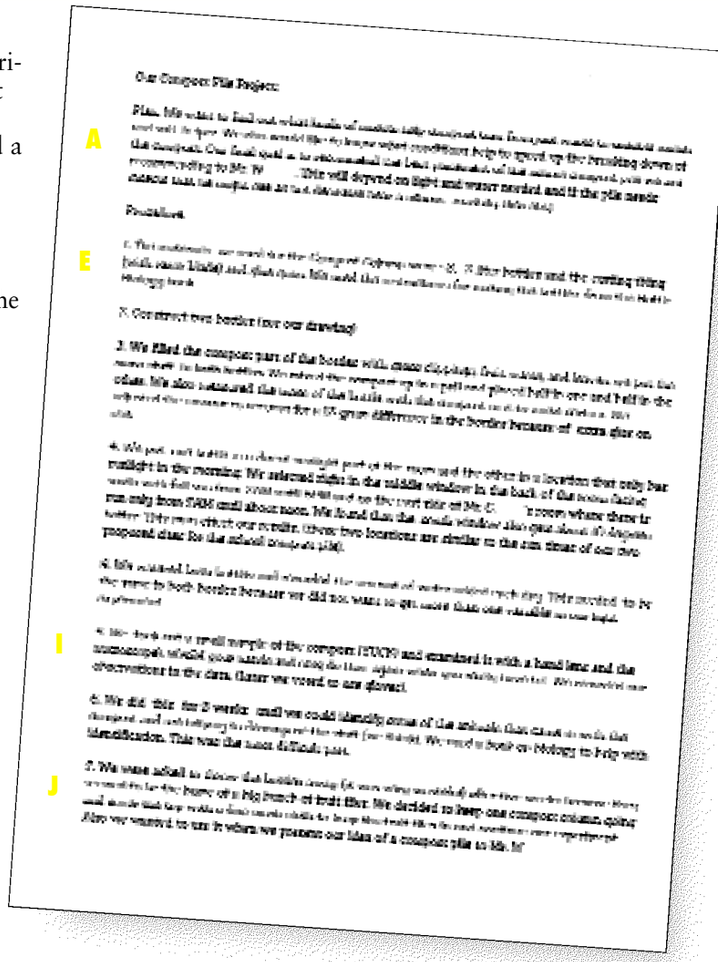
What the work shows

S2 d Life Sciences Concepts: The student produces evidence that demonstrates understanding of the interdependence of organisms, such as…cooperation and competition among organisms in ecosystems….

A B The work shows understanding of the interdependence of organisms, including populations, ecosystems, and food webs.

S4 a Scientific Connections and Applications: The student produces evidence that demonstrates understanding of the big ideas and unifying concepts, such as…models, form and function; change and constancy; and cause and effect.

C The compost bottle was a small scale model in which the variables could be controlled, then scaled up to the compost pile recommended in the conclusions.



Our Compost Pile Project:

A

E

I

J

D The discussion of the earwigs' niche shows an understanding of the interdependence of growth, population stress, and predator/prey relationships, all evidence of an understanding of change and constancy, and of cause and effect.

S6 a Scientific Tools and Technologies: The student uses technology and tools (such as traditional laboratory equipment…) to observe and measure…organisms and phenomena, directly….

E The students created the tools to make this investigation possible, overcoming the obstacle and impracticality of two full-size compost piles.

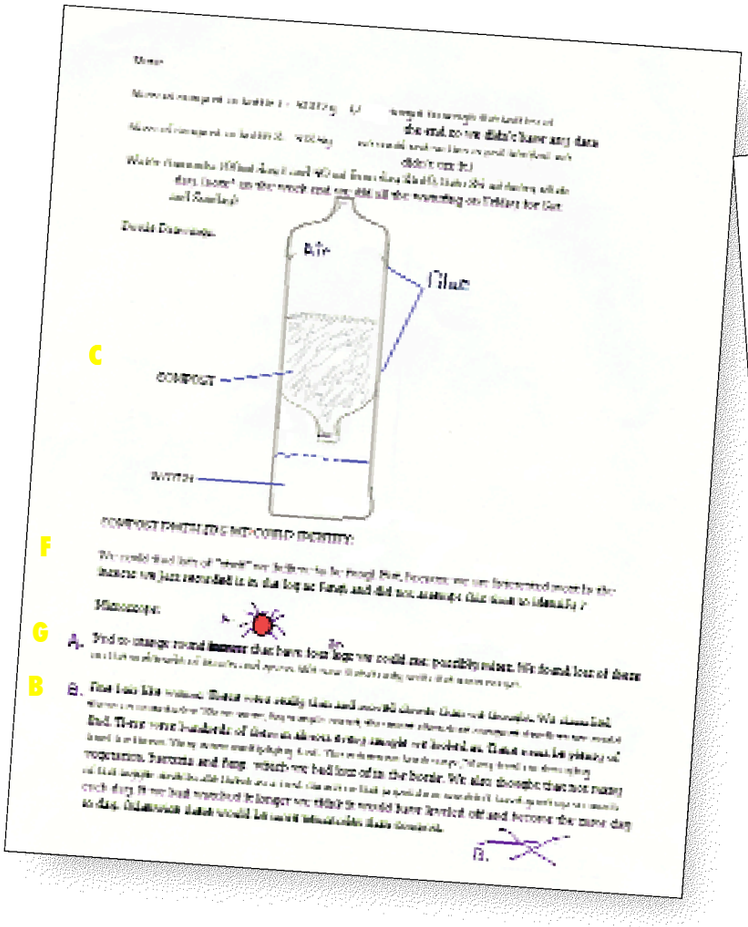
S6 d Scientific Tools and Technologies: The student acquires information from multiple sources such as print…and experimentation.

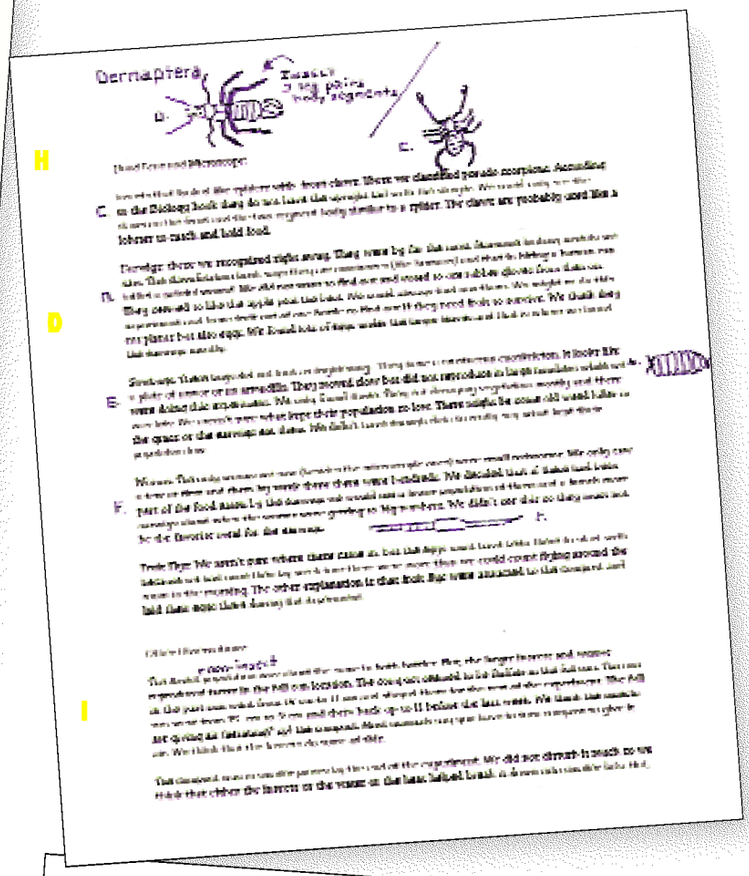
B D

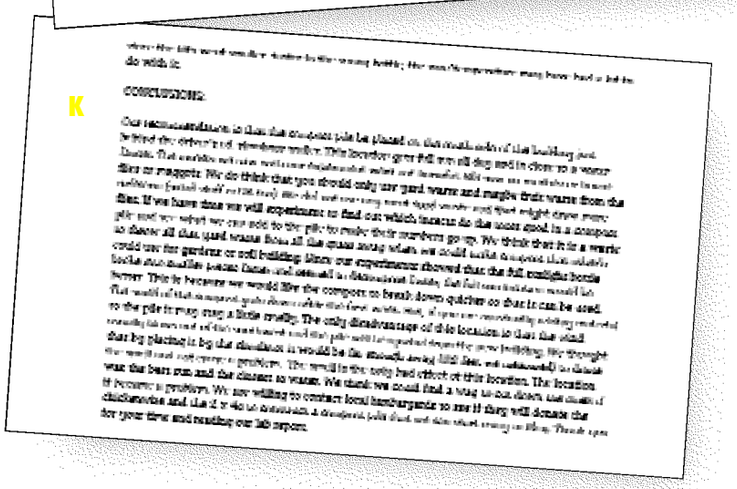
This work sample illustrates a standard-setting performance for the following parts of the standards:

- S2 d Life Sciences Concepts: Interdependence of organisms.
- S4 a Scientific Connections and Applications: Big ideas and unifying concepts.
- S6 a Scientific Tools and Technologies: Use technology and tools.
- S6 d Scientific Tools and Technologies: Acquire information from multiple sources.
- S7 a Scientific Communication: Represent data and results in multiple ways.
- S8 a Scientific Investigation: Controlled experiment.

Compost







S7 a Scientific Communication: The student represents data and results in multiple ways, such as…drawings…[and] technical writing….

F G The precision of the language, "we believe to be fungi" and "possibly mites," is excellent.

C H Drawings are used effectively.

S8 a Scientific Investigation: The student demonstrates scientific competence by completing a controlled experiment. A full investigation includes:

- **Questions that can be studied using the resources available.**

The work shows consideration of appropriate resources by scaling down the compost pile to conduct the investigation accurately and practically in a pop bottle.

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

I J The work also shows attention to safety and consideration for others.

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

This work shows thorough and appropriate documentation, both in the procedures and in the descriptions of the organisms that provide enough detailed information for others to replicate the investigation.

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

C F G H

The writing contains some spelling and grammatical errors, but these do not detract from the quality of the report.

- **Recommendations, decisions, and conclusions based on evidence.**

I The conclusion is drawn from evidence.

- **Acknowledgment of references and contributions of others.**

B E

- **Results that are communicated appropriately to audiences.**

K The conclusion of the report is an appropriate recommendation to the school principal, "Mr. W.," as to where the school should keep a compost pile.

- **Reflection and defense of conclusions and recommendation from other sources and peer review.**

Evidence of peer review is not included in this report.