Chapter 1

Assessment in Science Education

A Call for Change

There is much agreement within the science education community that current methods for assessing student achievement, primarily selected response tests, fall short of measuring standards that are part of contemporary science education. Most testing efforts, including standardized, norm-referenced, and teacher-designed tests, are not consistent with national and state standards and benchmarks. Some critics have gone so far as to charge that traditional assessments have been isolated from, and consequently are actually damaging to, instruction and learning (Jamentz, 1994). Also, many others contend that traditional assessments are merely used to sort students and, as a result, may deny educational opportunities (Darling-Hammond, 1991). If indeed these claims are the case, and if standard written tests are no longer adequate for measuring a student's performance on the standards of science instruction, then what kinds of alternative assessments are needed? What guiding philosophies and principles will be used to shape these new assessments? What formats will these assessments take? Who will design them?

Current thinking is that science instruction must be evaluated using quite different techniques and tools. Techniques are needed that show not only what students know, but also how students actually use and apply information and skills. If we want students to solve problems, answer open-ended questions, and actually perform as is called for by many educational reformers (Silver, Strong, & Perini, 2000), then tests must be developed that measure performance. Most traditional paper-and-pencil tests that evaluate answers as being either right or wrong cannot adequately evaluate performance. Think about the work of an architect, an engineer, a musician, a teacher, a baseball player, or a writer. Either a performance or a product is the basis for evaluating their work. These people do not take paper-and-pencil tests to demonstrate what they know—they perform! The question "Why don't we apply these same ideas to teaching and assessing student achievement?" naturally arises at this point.

When students are assessed based upon their performance, then constant feedback will become an integral part of the instructional process. If we take this approach, assessment becomes a process and not an event. A coach works constantly with his or her players to improve upon their performance. The same approach can and should apply to teaching science. The sequence of teach, assess, and adjust instruction based upon the results of assessment is a methodology that works to improve performance. Think back to a class you took in college. Didn't you typically do your best work when you were allowed to develop a draft, get feedback from the professor, and then make revisions before turning in the final product?

USING NATIONAL AND STATE STANDARDS TO IMPLEMENT CHANGE

National science standards from the American Association for the Advancement of Science (1993) and the National Research Council (1996) have been part of the science education environment for about 10 years. More recently, state-specific science standards have come to dominate the science curriculum for growing numbers of students. But this movement is not without controversy, because some have criticized state standards as being inadequate (Lerner, 1998). And teachers, administrators, students, and parents alike continue to question the need for such standards. Standards for some seem unnecessarily burdensome to implement, seem restrictive to the curriculum, and lead to increased testing. Their skepticism is somewhat justified in light of the numerous supposedly "innovative practices" that have been perpetuated upon them in the past and that, in many cases, were based upon nothing more than someone's good idea, without any real supporting evidence from field studies.

It has become increasingly evident that if science educators are ever going to enthusiastically embrace these standards, then they must have opportunities to "unpackage" standards by interpreting their intent and by designing units of study. In so doing, standards will become "real" and useful to them, especially when they continue to learn through gathering evidence from students that a standard has been met or progress is being made toward meeting it.

The encouraging news is that the continued use of standards and assessment of standards in educational settings is leading many educators to believe that standards can indeed

- Lead to improved student performance (Andrade, 1997; Marzano, 2001)
- Motivate educators to explore questions at the very heart of the purposes and processes of schooling (Jamentz, 1994)
- Provide both students and teachers with developmentally appropriate benchmarks of student performance that can be used to design performance tasks and performance-based units
- Provide both students and teachers with well-defined criteria by which to assess student performance and understanding
- Provide the foundation for the development of a focused professional development program for all stakeholders
- Provide a stable foundation upon which instructional programs of excellence can be constructed and maintained year after year (Lantz, 2001)
- Provide for quality control and consistency of teaching, assessment, and accountability across classrooms, schools, and school districts
- Provide ample opportunities for students to become more thoughtful judges of the quality of their own work and to revisit past performances so as to improve upon them
- Reduce the amount of time teachers spend evaluating student work, as a result of more student self- and peer review

Today's science standards are comprehensive in skills and processes, inquiry, and science content; are robust and rich; often have multiple "right" answers; and require performances to assess them. Consequently, traditional modes of assessment alone are not sufficient to gather evidence of student understanding of these standards. As a result, complementary and alternative forms of assessment have emerged. Alternative assessment means any assessment format that is nontraditional and requires the student to construct, demonstrate, or perform (Doran, Chan, & Tamir, 1998).

ASSESSMENT TECHNIQUES

When it comes to assessment, there exists a good news-bad news scenario. The good news is that classroom teachers already use a variety of assessment techniques that could be used to evaluate performance. The bad news is that these techniques are generally thought of as informal assessment methods and are rarely used for formal grading or adjustment of instruction.

In the science classroom, any behavior that can be observed can be assessed. Observing what students write, say, and do can form the foundation for assessing performance. Projects, interviews, conferences, presentations, journals, logs of data and observations, lab reports, extended studies, and student self-assessments are all performances that can provide evidence of student understanding or lack thereof. Unfortunately, the power of using assessment of these types of performances for formative feedback and adjustment of instruction still remains unrealized in many science classrooms of today. Here is where the concept of the performance task takes center stage.

PERFORMANCE TASKS

The purpose of a performance task is to assess what students know and what they can do with what they know. The use of performance tasks to assess student achievement, particularly science process skills, has been well documented. Their reliability and validity parallels that of traditional assessments (Adams & Callahan, 1995). Science performance tasks take many formats depending upon their intended audience and purpose. However, according to Wiggins and McTighe in *Understanding by Design* (1998), performance tasks should consist of complex challenges that reflect problems and issues faced by adults. In addition, the task should be meaningful, authentic, and worth mastering. Typically, the student knows in advance the goal, the role, the audience, the setting, the product or performance, and the standards against which work will be assessed (McTighe, 1999). Performance tasks, when used as summative assessments for a unit of study, serve to hook the student, activate prior knowledge, and let the student know where the unit is headed.

The following criteria are often used to shape performance tasks. A science performance task should

- Provide opportunities for students to demonstrate and communicate their understanding of standards, benchmarks, goals, objectives, and science content (Baron, 1991)
- Serve to anchor the unit, lesson, or performance (Wiggins & McTighe, 1998)
- Afford students an opportunity to demonstrate their *understanding* of science and not just provide a single, best, and often superficial answer
- Integrate knowledge and skills within the disciplines of science, language arts, and mathematics
- Be meaningful, authentic, interesting, challenging, and thought-provoking, and have cognitively appropriate content (Baron, 1991)
- Stress depth over breadth
- Allow for multiple approaches, solutions, and answers and not have one clear path of action specified at the beginning of the task
- Raise other questions or lead to other problems

ASSESSING STUDENT ACHIEVEMENT ON PERFORMANCE TASKS

Performance tasks, by their very nature, cannot be evaluated using traditional paper-and-pencil tests. Performance tasks involve understanding of scientific concepts and procedures; stimulate depth of thought, are usually open-ended, and seldom have one correct answer. The evaluation of such tasks involves the development of assessment tools and the professional judgment of trained educators. Before challenging students to attempt a performance, the teacher should explain the task, give the students written criteria, discuss the criteria, and provide examples of exemplary performance (anchors). Criteria should always be in writing and well understood by everyone before student performances begin.

The first step in evaluating a performance task is to establish a system of documenting students' performances. Two assessment tools—the Performance List Rubric (Chapter 2) and the Holistic and/or Analytic Rubric (Chapter 3)—are presented within this text. Both are versatile and effective techniques. They are not merely abstract numbering systems but instead are a taxonomic system that provides specific assessment guidelines for teachers and students alike. Both can provide not only summative but also formative assessments.

To be used effectively, these two assessment tools must be used at various stages throughout the performance. This gives students a chance to perform, receive feedback, and revise their work. Thus, the performance list rubric and the holistic and/or analytic rubric allow students and teachers to establish a classroom environment in which risk taking and creativity are rewarded. Students are given credit for making incremental progress toward a goal and are not penalized for a lack of immediate success (Treagust, Jacobowitz, Gallagher, & Parker, 2003).

Assessment tools can be general (non-task specific), or they can be developed to measure student progress toward mastery of specific skills and knowledge. Whatever tool (specific or non-task specific) is used, criteria must be clear and unambiguous so that students know what performance is needed to reach educational goals.

Performance assessments allow students to compete with themselves, rather than with other students. Through such assessments, students can gain a real understanding of what they know and what they can do. Performance assessments, unlike written tests, need not be threatening. Because there are many correct answers, performance assessments can take the fear out of learning science. Taking the fear and anxiety out of the science classroom may motivate many more students to continue their study of science. They will also enjoy, learn, and use more science. Performance assessment makes school learning more relevant to students' lives and the real world. It helps teachers focus on the really important outcomes of education, instead of teaching isolated bits of information. As students learn to become competent problem solvers and to be confident of their ability to think logically and communicate their ideas clearly, they will recognize that they have received an education that has prepared them for life—for life as productive citizens in the 21st century.

What Might a Performance List Rubric Look Like for a Second-Grade Performance Task?

Example 1. Signals of Spring

Ms. Logan, principal of Mother Jones Elementary School, wants to plant 1,000 tulips this fall so that they will be ready to bloom in the spring. Like all plants, tulips need air, water, and food to live. Plants get most of their water from the soil in which they are planted. Before the tulips can be planted, you need to find out if the soil is the right kind of soil for the tulips. You will test the soil at Mother Jones as well as other kinds of soil to see which would be the best for growing tulips. Then you will communicate your results to Ms. Logan through scientific drawings and a report to tell her how to best prepare the soil for the tulips.

Example 1 is a performance task that has been used successfully with elementary students in Grade 2. This task was designed to address the following national standards:

Project 2061 Benchmarks

Everyone can do science and invent things and ideas. (Chapter 1C, The Nature of Science: Grades K-2)

People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to things and noting what happens. (Chapter 1B, The Nature of Science: Grades K-2)

Plants and animals have features that help them live in different environments. (Chapter 5, The Living Environment: Grades K-2)

Most living things need water, food, and air. (Chapter 5, The Living Environment: Grades K-2)

National Science Education Standards

Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world. (Content Standard A: Science as Inquiry: Grades K-4)

Scientists make the results of their investigations public; they describe the investigation in ways that enable others to repeat the investigations. (Content Standard A: Science as Inquiry: Grades K-4)

Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms. (Content Standard C: Life Science: Grades K-4)

The performance list rubric that was used to assess the scientific drawings of the students in Example 1 appears in Figure 1.1.

The columns labeled "Self" and "Teacher" can be used in several ways. Checkmarks (✓) could be placed in the column "Self" if the student believes the criterion is present in his or her performance. The teacher can then add checks in the "Teacher" column to validate and reinforce the student's self-assessment. Or each criterion (1-4) could be weighted by designating points for each, and then "Self" and/or "Teacher" assessments can be completed.

What Might a Performance List Rubric Look Like for a Fourth-Grade Performance Task?

Example 2. Crumbling Monuments

Have you ever heard of acid rain? You may have heard newscasters talking about it on television or read about it in a newspaper or magazine. What exactly is acid rain, and how harmful is it? How does it affect plants, animals, buildings, and people? The Capitol building is a national monument that is being affected by acid rain.

In order to understand acid rain, you need to know what acids are. In this unit, you will first explore acids and bases and how scientists identify them. You will then learn about acid rain. At the end of the unit, you will create a PowerPoint presentation on acid rain that could be shown during morning announcements at your school. The purpose of your presentation is to make students aware of the problem of acid rain. You may want to review the performance list rubric for "PowerPoint Presentation" before you begin.

Example 2 is a performance task that has been used successfully with elementary students in Grade 4. This task was designed to address the following national standards:

Project 2061 Benchmarks

Technologies often have drawbacks as well as benefits. A technology that helps some people or organisms may hurt others—either deliberately (as weapons can) or inadvertently (as pesticides can). When harm occurs or seems likely, choices have to be made or new solutions found. (Chapter 3C, Issues in Technology: Grades 3-5)

When liquid water disappears, it turns into a gas (vapor) in the air and can reappear as a liquid when cooled, or as a solid if cooled below the freezing point of water. Clouds and fog are made of tiny droplets of water. (Chapter 4B, The Physical Setting: Grades 3-5)

Scientific Drawing

Name ____________________

Date ____________________

Topic ____________________

Performance Criteria		Assessment		
		Points	**Self**	**Teacher**
1.	My scientific drawing shows details of what I actually observed.			
2.	All parts of my scientific drawing are clearly and accurately labeled.			
3.	My drawing has a title that explains what the drawing is all about.			
4.	My scientific drawing is large enough to see all parts clearly.			

Teacher Comments:

Figure 1.1 An Example of a Performance List Rubric for a Scientific Drawing for Grades 2-3

For any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all. (Chapter 5D, Interdependence of Life: Grades 3-5)

National Science Education Standards

Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world. (Content Standard A: Science as Inquiry: Grades K-4)

Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations. (Content Standard A: Science as Inquiry: Grades K-4)

Materials can exist in different states—solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling. (Content Standard B: Physical Science: Grades K-4)

Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms. (Content Standard C: Life Science: Grades K-4)

Earth materials are solid rocks and soils, water, and the gases of the atmosphere. The varied materials have different physical and chemical properties, which make them useful in different ways, for example, as building materials, as sources of fuel, or for growing the plants we use as food. Earth materials provide many of the resources that humans use. (Content Standard D: Earth and Space Science: Grades K-4)

The performance list rubric that was used to assess the PowerPoint Presentation of the students in Example 2 appears in Figure 1.2.

What Might a Performance List Rubric and a Holistic Rubric Look Like for a Middle School (Grade 7) Performance Task?

Example 3. Get Into the Swing

For generations, your family has owned an antique grandfather clock. Recently, your grandparents gave the clock to your family as a present. However, during transport of the clock, the pendulum became detached. The pendulum has been reattached and the clock has been set up at your home, but it no longer keeps accurate time. Members of your family all have different opinions about how to adjust the pendulum so the clock will keep accurate time again. Your sister believes that if you adjust the length of the pendulum, you will be able to correct the problem. Your father believes that if you change the mass of the pendulum, you can increase its accuracy. Your mother believes that if you adjust the amplitude (the amount of displacement of the pendulum from its resting position), you can correct the problem. Your grandparents are quite concerned. What do you think?

You need to communicate with your grandparents, advising them of your solution. One format you might want to consider is a friendly letter. If you choose this format, you might want to review the performance list rubric and/or the holistic rubric “Writing to Inform” before you begin. Regardless of how you communicate

PowerPoint Presentation

Name ____________________ Date __________ Course/Class __________

Task/Assignment ____

Performance Criteria	Assessment			
	Points	**Self**	**Teacher**	**Other(s)**
1. The topic has been extensively and accurately researched.				
2. A storyboard, consisting of logically and sequentially numbered slides, has been developed.				
3. The introduction is interesting and engages the audience.				
4. The fonts are easy to read and point size varies appropriately for headings and text.				
5. The use of italics, bold, and underline contributes to the readability of the text.				
6. The background and colors enhance the text.				
7. The graphics, animations, and sounds enhance the overall presentation.				
8. Graphics are of proper size.				
9. The text is free of spelling, punctuation, capitalization, and grammatical errors.				

Comments	Goals	Actions

Figure 1.2 An Example of a Performance List Rubric for PowerPoint Presentation for Grades 4-6

your results, it will be evaluated based upon how well you organize and develop the topic using appropriate and scientifically correct language.

Example 3 is a performance task that has been used successfully with seventh-grade students at the end of an integrated science unit on force and motion, gravity and microgravity, and pendulums. This task was designed to address the following national standards:

Project 2061 Benchmarks

Everything on or anywhere near the earth is pulled toward the earth's center by gravitational force. (Chapter 4, The Physical Setting: Grades 6-8)

National Science Education Standards

The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph. (Content Standard B: Physical Science: Grades 5-8)

The performance list and holistic rubrics that were used to assess student work in example #3 appear in Figures 1.3 and 1.4.

What Might a Performance List Rubric and an Analytic Rubric Look Like for an Earth Science Performance Task?

Example 4. Cruising Contours

Many people love winter sports, and sledding is a popular one. On a cold, snowy day, all that is needed is something to slide on and a hill with a steep pitch. Then, let gravity do the work and enjoy the ride. You may know where there are sled runs in your neighborhood, but most hills in Prince George's County, Maryland, are not steep or long. Did you ever wonder why?

Snowboarding and downhill skiing are sports that you as a teenager really enjoy. However, they require slopes much steeper than the hills found locally. There are no ski resorts in Prince George's County. Are there ski resorts anywhere in the state of Maryland?

Your task is to research the location of existing ski resorts in Maryland and apply what you have learned about landforms, topography, natural resources, and heat and sunlight to explain why the resorts were built there. In addition, you are to propose and defend the location of another future ski resort in Maryland, using topographic maps to fully explain your decision. You are to develop a presentation (you decide the format) for the local Chamber of Commerce of the county in which you wish to propose your new skiing/ snowboarding area. Your presentation will be evaluated based upon its clarity, organization, use of language, correct use of scientific concepts, supporting data, and persuasiveness.

Example 3 is a performance task that has been used successfully with earth science students at the end of an integrated unit on landforms, topography, heat and sunlight, and natural resources. This task was designed to address the following national standards:

National Science Education Standards

Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion. (Content Standard D: Earth and Space Science: Grades 5-8)

Writing to Inform in Science

Name ______________________ Date ____________ Course/Class ____________

Task/Assignment ____

Performance Criteria	Assessment: Points	Self	Teacher	Other(s)
1. Accurate, specific, and purposeful scientific facts and concepts are included and are extended and expanded to fully explain the topic.				
2. A logical organizational plan for the text is established and consistently maintained.				
3. Scientific information that is relevant to the needs of the audience is used throughout the text.				
4. Scientific vocabulary and language choices enhance the text.				
5. Diagrams, pictures, and other graphics are of quality and add to the overall effectiveness of the text.				
6. There are no errors in the mechanics (spelling and grammar).				

Comments	Goals	Actions

Figure 1.3 An Example of a Performance List Rubric for Writing to Inform for Grades 7-12

Writing to Inform in Science

Name ___________________________ Date ________________ Course/Class _____________

Task/Assignment ____

Expert 4	Development: The writer provides accurate, specific, and purposeful scientific facts and concepts that are extended and expanded to fully explain the topic. Organization: The writer establishes an organizational plan and consistently maintains it. Audience: The writer provides scientific information relevant to the needs of the audience. Language: The writer consistently provides scientific vocabulary and language choices to enhance the text. There are no errors in the mechanics (spelling and grammar.)
Proficient 3	Development: The writer provides scientific facts and concepts that adequately explain the topic with some extension of ideas. The information is usually accurate and purposeful. Organization: The writer establishes and maintains an organizational plan, but the plan may have some minor flaws. Audience: The writer provides information most of which is relevant to the needs of the audience. Language: The writer frequently provides scientific vocabulary and uses language choices to enhance the text. There are few errors in the mechanics (spelling and grammar).
Emergent 2	Development: The writer provides scientific facts and concepts that inadequately explain the topic. The information is sometimes inaccurate, general, or extraneous. Organization: The writer generally establishes and maintains an organizational plan. Audience: The writer provides some information relevant to the needs of the audience. Language: The writer sometimes provides scientific vocabulary and uses language choices to enhance the text. There are significant errors in the mechanics (spelling and grammar.)
Novice 1	Development: The writer provides insufficient scientific facts and concepts to explain the topic. The information provided may be vague or inaccurate. Organization: The writer either did not establish an organizational plan or, if an organizational plan is established, it is only minimally maintained. Audience: The writer did not provide information relevant to the needs of the audience. Language: The writer seldom, if ever, provides scientific vocabulary and uses language choices to enhance the text. There are many errors in the mechanics (spelling and grammar).

Comments	Goals	Actions

Figure 1.4 An Example of a Holistic Rubric for Writing to Inform for Grades 7-12

> The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation. (Content Standard B: Physical Science: Grades 5-8)

The performance list and analytic rubrics that were used to assess student work appear in Figures 1.5 and 1.6. The two small boxes in each cell of the analytic rubric could be used for placing checkmarks (✓) for self-, peer, teacher, and/or other assessments.

What Might a Performance List Rubric Look Like for a High School Chemistry Performance Task?

Example 5. Warming Up to Chemistry

For years, your extended family has taken a skiing/snowboarding trip to New England. You usually hang out with your cousin, who is the same age as you and who is also taking chemistry. There's only one problem: You have to stop often to go inside and warm up because your cousin's hands and feet get cold. You want to spend time with your cousin this year as well, but you don't want to have to stop all the time. You decide to do a little research and investigate the "toe heaters" and "hand warmers" people have told you about. Once you've finished your investigation, you will write a letter to your cousin explaining how the hot packs work and why he should consider using them. You will also include other suggestions about keeping warm in winter. Your cousin is a real science buff and fellow chemistry student, so you'll have to explain the scientific concepts completely, accurately, and in an organized fashion.

Example 5 was a performance task used with students in chemistry at the end of a unit on thermochemistry. The following national standards are addressed within this unit:

Project 2061 Benchmarks

> Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much total energy remains, its being spread out more evenly means less can be done with it. (Chapter 4, The Physical Setting: Grades 9-12)

> The rate of reactions among atoms and molecules depends on how often they encounter one another, which is affected by the concentration, pressure, and temperature of the reacting materials. Some atoms and molecules are highly effective in encouraging the interaction of others. (Chapter 4, The Physical Setting: Grades 9-12)

National Science Education Standards

> Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and evolution of urban smog. (Content Standard B: Physical Science: Grades 9-12)

> Chemical reactions can take place in time periods ranging from the few femtoseconds (10–15 seconds) required for an atom to move a fraction of a chemical bond distance to geologic time scales of billions of years. Reaction rates depend on how often the reacting atoms and molecules encounter one another, on the temperature, and on the properties—including shape—of the reacting species. (Content Standard B: Physical Science: Grades 9-12)

The task-specific holistic rubric used to assess student work in Example 5 appears in Figure 1.7.

Writing to Persuade in Science

Name ____________________ Date __________ Course/Class __________

Task/Assignment ____

Performance Criteria	Assessment			
	Points	Self	Teacher	Other(s)
1. A clear position is established that is fully supported or refuted with relevant, accurate scientific and/or personal information.				
2. A logical organizational plan for the text is established and consistently maintained.				
3. Scientific information that is relevant to the needs of the audience is used throughout the text.				
4. Scientific vocabulary and language choices enhance the position.				
5. Diagrams, pictures, and other graphics are of quality and add to the overall effectiveness of the position.				
6. There are no errors in the mechanics (spelling and grammar).				

Comments	Goals	Actions

Figure 1.5 An Example of a Performance List Rubric for Writing to Persuade for Grades 7-12

Writing to Persuade in Science (Analytic Rubric)

Name ______________________ Date ____________ Course/Class ______________________________

Task/Assignment ____

	Development	Organization	Audience	Language
Expert **4**	Development: The writer identifies a clear position and fully supports or refutes that position with relevant, accurate scientific and/or personal information. ❑ ❑	Organization: The writer presents an organizational plan that is logical and consistently maintained. ❑ ❑	Audience: The writer effectively addresses the needs and characteristics of the identified audience. ❑ ❑	Language: The writer consistently uses relevant, scientific vocabulary and language choices to enhance the text. ❑ ❑
Proficient **3**	Development: The writer identifies a clear position and partially supports or refutes that position with relevant, accurate scientific and/or personal information. ❑ ❑	Organization: The writer presents an organizational plan that is logical and maintained, but with minor flaws. ❑ ❑	Audience: The writer adequately addresses the needs and characteristics of the identified audience. ❑ ❑	Language: The writer frequently uses relevant, scientific vocabulary and language choices to enhance the text. ❑ ❑
Emergent **2**	Development: The writer identifies a position, yet that position lacks clarity. The writer tries to support or refute that position with relevant, accurate scientific and/or personal information. ❑ ❑	Organization: The writer presents an organizational plan that is only generally maintained. ❑ ❑	Audience: The writer minimally addresses the needs and characteristics of the identified audience. ❑ ❑	Language: The writer sometimes uses scientific vocabulary and language choices to enhance the text. ❑ ❑
Novice **1**	Development: The writer identifies an ambiguous position with little or no relevant, accurate scientific and/or personal information to support that position; or the writer fails to identify a position. ❑ ❑	Organization: The writer presents an argument that is illogical and/or minimally maintained. ❑ ❑	Audience: The writer does not address the needs and characteristics of the identified audience. ❑ ❑	Language: The writer seldom, if ever, uses scientific vocabulary and language choices to enhance the text. ❑ ❑

Figure 1.6 An Example of an Analytic Rubric for Writing to Persuade for Grades 7–12

Task-Specific Holistic Rubric for "Warming Up to Chemistry"

Name ___________________________ Date ________________ Course/Class _____________

Task/Assignment ____

Expert 4	The following concepts are completely and accurately explained in the letter: heat and temperature and their differences; kinetic energy and temperature; heat transfer and measurement; endothermic and exothermic reactions; positive and negative enthalpy and surroundings; Hess's Law; enthalpy and entropy; and Gibbs free energy. The response includes a recommendation for a hot pack that is extensively supported, along with its availability and cost analysis.
Proficient 3	The following concepts are mostly explained in the letter: heat and temperature and their differences; kinetic energy and temperature; heat transfer and measurement; endothermic and exothermic reactions; positive and negative enthalpy and surroundings; Hess's Law; enthalpy and entropy; and Gibbs free energy. The response includes a recommendation for a hot pack that is supported, along with its availability and cost analysis.
Emergent 2	The following concepts are partially explained in the letter: heat and temperature and their differences; kinetic energy and temperature; heat transfer and measurement; endothermic and exothermic reactions; positive and negative enthalpy and surroundings; Hess's Law; enthalpy and entropy; and Gibbs free energy. The response includes a recommendation for a hot pack, but without being supported. Availability and cost analysis of the hot pack may or may not be included.
Novice 1	The following concepts are explained in the letter, but contain many misunderstandings and misconceptions: heat and temperature and their differences; kinetic energy and temperature; heat transfer and measurement; endothermic and exothermic reactions; positive and negative enthalpy and surroundings; Hess's Law; enthalpy and entropy; and Gibbs free energy. The response may or may not include a recommendation for a hot pack

Comments	Goals	Actions

Figure 1.7 An Example of a Task-Specific Holistic Rubric for Chemistry

What Might a Performance List Rubric Look Like for a High School Biology Performance Task?

Example 6. The Great Divide

A local middle school science teacher, Ms. Jones, wants to start a mentoring program in science for her seventh-grade classes and wants high school students to be the mentors. Middle school students are most impressed by high school students, so your impact upon them could be tremendous. The first topic Ms. Jones wants you to teach the middle school students is—you guessed it—cell division, including mitosis and meiosis! But it has been several years since you last studied cell division, so you know you need to brush up. As a result, your biology teacher has developed the following unit for you to refresh your memory. At the end of this unit, you must demonstrate that you understand mitosis and meiosis well enough to teach it to seventh-grade students. To do this, you must be able to develop a poster comparing mitosis and meiosis that you can use to teach the middle school students. You will also prepare a clear written explanation of mitosis and meiosis. Are you ready?

Example 6 was a performance task used with students in biology at the end of a unit on cell division. The following national standards are addressed within this unit:

Project 2061 Benchmarks

Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere. The rules may range from very simple to extremely complex, but scientists operate on the belief that the rules can be discovered by careful, systematic study. (Chapter 1A: The Scientific World View: Grades 9-12)

The degree of kinship between organisms or species can be estimated from the similarity of their DNA sequences, which often closely match their classification based on anatomical similarities. (Chapter 5A: Diversity of Life: Grades 9-12).

The information passed from parents to offspring is coded in DNA molecules. (Chapter 5B: Heredity: Grades 9-12)

National Science Education Standards

Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires. (Content Standard C: Life Science: Grades 9-12)

Most of the cells in a human being contain two copies of each of the 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome—and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next. (Content Standard C: Life Science: Grades 9-12)

Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism's offspring. (Content Standard C: Life Science: Grades 9-12)

The rubric used to assess student work in Example 6 appears in Figure 1.8.

What Might a Performance List Rubric Look Like for a High School Physics Performance Task?

Example 7. Charge! On the Move

Welcome to Mr. Covert's Physics Challenge of the Month. Your challenge is to purchase and install a new kick-bass car stereo system in your car. You have a budget of $2,000 to spend on your equipment. Using your knowledge of series and parallel circuits and Ohm's Law, you will have to plan and design the best way to connect the speakers to the amplifier to maximize the power output of the amplifier, but not burn out the amp. You will also need to include a cost analysis for the equipment purchased. Note: You must have at least four 8-ohm speakers and only one amplifier to run the system. The choice of stereo, equalizer, and other equipment is entirely up to you. You must have the following items in this project:

- Cost analysis of equipment to purchase that includes item name, manufacturer of item, place of purchase, and cost
- Schematic diagram of circuit including battery, fuse, radio, equalizer and effects, power amplifier, and speakers
- Calculation of effective resistance of circuit
- Calculation of current drawn from battery and recommended fuse size for the circuit

At the end of your preparation for the challenge, you must present your findings orally in a convincing, clear, and scientifically accurate way. You may use any visual you wish in your presentation.

Example 7 was a performance task used with students in physics at the end of a unit on series and parallel circuits and application of Ohm's Law to various series and parallel circuits.

The following national standards are addressed within this unit. Students discover the properties of series and parallel circuits.

Project 2061 Benchmarks

Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere. The rules may range from very simple to extremely complex, but scientists operate on the belief that the rules can be discovered by careful, systematic study. (Chapter 1A: The Nature of Science: Grades 9-12)

Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories. (Chapter 1B: Scientific Inquiry: Grades 9-12)

Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available). (Chapter 1B: Scientific Inquiry: Grades 9-12)

Poster

Name ____________________ Date ____________ Course/Class ____________

Task/Assignment ____

Performance Criteria	Assessment			
	Points	Self	Teacher	Other(s)
1. The poster contains a title that clearly reflects the topic or theme.				
2. The poster contains relevant and accurate information about the topic or theme.				
3. The format of the poster is appropriate to the content, purpose, and audience for which it is designed.				
4. Graphic elements, such as pictures, photographs, charts, tables, scientific drawings, diagrams, graphs, etc., add to the overall effectiveness of the poster.				
5. There is a coherent, flowing organization to the poster with the various elements (text, graphics, etc.) working well together.				
6. The poster is aesthetically pleasing, with effective use of space, color, texture, and shape.				
7. The poster is skillfully designed and crafted using appropriate graphic design tools.				
8. The poster effectively communicates its theme in convincing fashion to the intended audience.				
9. The poster is creative and draws attention.				
10. Language chosen for the poster is captivating, persuasive, informative, accurate, and concise.				

Comments	Goals	Actions

Figure 1.8 An Example of a Performance List Rubric for Poster for Grades 7-12

Mathematics provides a precise language for science and technology—to describe objects and events, to characterize relationships between variables, and to argue logically. (Chapter 2B: Mathematics, Science, and Technology: Grades 9-12)

Any mathematical model, graphic or algebraic, is limited in how well it can represent how the world works. The usefulness of a mathematical model for predicting may be limited by uncertainties in measurements, by neglect of some important influences, or by requiring too much computation. (Chapter 9B: Symbolic Relationships: Grades 9-12)

Tables, graphs, and symbols are alternative ways of representing data and relationships that can be translated from one to another. (Chapter 9B: Symbolic Relationships: Grades 9-12)

When a relationship is represented in symbols, numbers can be substituted for all but one of the symbols and the possible value of the remaining symbol computed. Sometimes the relationship may be satisfied by one value, sometimes more than one, and sometimes maybe not at all.

The reasonableness of the result of a computation can be estimated from what the inputs and operations are. (Chapter 9B: Symbolic Relationships: Grades 9-12)

National Science Education Standards

Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results. (Content Standard A: Science as Inquiry: Grades 9-12)

The electric force is a universal force between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them. (Content Standard B: Physical Science: Grades 9-12)

In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons. (Content Standard B: Physical Science: Grades 9-12)

The performance list rubric used to assess student work in Example 7 appears in Figure 1.9.

IMPLEMENTING PERFORMANCE TASKS IN THE SCIENCE CLASSROOM

By reviewing the examples above, it is obvious that good performance tasks and assessment tools (performance list rubrics, holistic rubrics, and/or analytic rubrics) take time to construct, field test, and revise. Also, an assessment consisting of rubrics cannot be scored as quickly and as easily as a selected response item. The obvious question that comes to mind at this time is, "Do I, as a very busy classroom teacher, have the time to do this kind of performance evaluation?" The answer is an unequivocal yes. But it may mean that you will have to modify your pedagogy to make your classroom more performance based and student centered, rather than being primarily teacher directed. You may need to meaningfully engage students, provide explorations for data collection and analysis, and give students opportunities to develop and demonstrate

Oral Presentation in Science

Name ____________________________ Date ______________ Course/Class _____________

Task/Assignment ____

Performance Criteria	Assessment			
	Points	**Self**	**Teacher**	**Other(s)**
Content and Organization 1. The purpose of the presentation (informing, persuading, or both), the subject, and any position taken by the presenter are clearly defined at the outset.				
2. The presentation is made in an interesting, logical sequence – an introduction, an organized body, and a clear closure – that the audience can follow.				
3. The introduction has a strong purpose statement that serves to captivate the audience and narrow the topic.				
4. An abundance of accurate supporting scientific concepts, facts, figures, statistics, scenarios, stories, and analogies are used to support the key points and ideas.				
5. The vocabulary is appropriate to both the science content and the audience.				

Figure 1.9 An Example of a Performance List Rubric for Oral Presentation for Grades 7-12

Oral Presentation in Science (continued)

Performance Criteria	Assessment			
	Points	**Self**	**Teacher**	**Other(s)**
Optional 6. Interesting and colorful audiovisual aids or multimedia materials are interwoven to explain and reinforce the screen text and presentation.				
7. The topic is developed completely and thoroughly.				
Presentation 8. The speaker maintains a proper volume, clear elocution, steady rate, effective inflections and enthusiasm throughout the presentation.				
9. Humor is used positively and in good taste, with consideration given to the composition of the audience.				
10. Stories and motivational scenarios are used appropriately.				
11. Body language such as eye contact, posture, gestures, and body movements are appropriate and are used to create effect.				
12. Delivery is well paced, flows naturally, has good transitions, and is coherent.				
13. The speaker is relaxed, self-confident, and appropriately dressed for purpose or audience.				

(Continued)

Oral Presentation in Science (continued)

Performance Criteria	**Assessment**			
	Points	**Self**	**Teacher**	**Other(s)**
Audience 14. The audience's attention is maintained by involving them in the presentation.				
15. Information needed by audience to fully understand the presentation is provided.				
16. The speaker gives the audience time to think, reflect, and ask questions about points made in the presentation.				
17. The speaker answers all questions with clear explanations and further elaborations.				
18. The topic and the length of the presentation are appropriate for the audience and within the allotted time limits.				

Comments	Goals	Actions

conceptual understandings through some of their products or performances, such as projects, presentations, or portfolios. And, in all likelihood, you will probably need to reduce your dependence on paper-and-pencil tests. By revising performance tasks over several years, the product only gets sharper and better. This is not necessarily the case with adopting new textbooks every 5 to 10 years.

Teachers often ask in workshops and in college classes, "What is a good source of performance tasks or materials that can be modified to build tasks?" Contemporary science materials, textbooks, and laboratory manuals that emphasize an inquiry-based, constructivist approach, and/or a 5E teaching and learning cycle, are an excellent source of potential performance tasks. Most of the programs endorsed by the National Science Foundation fall into this category. After students have completed an activity, you can very often assess their comprehension of the concept and/or process skills covered by having them repeat the activity with changed variables or hypotheses. Or, you can ask the students to rewrite and improve upon the procedures for completing the activity. Problems or examples from textbooks can be turned into simple performance tasks by asking a student to support his or her answers. Asking questions that probe understanding of why something works in science, and not always how it works, shifts the focus from convergent thinking to divergent thinking and, in so doing, aligns the questions with process goals of instruction.

For example, a group of fifth-grade students is studying concepts of simple machines. By looking at textbook pictures, they can identify various simple machines. They can draw them in their journals—one form of performance. The teacher listens to their conversation and then asks how many simple machines there are within everyday objects, such as skateboards and bicycles. Then, by observing an actual bicycle, the students observe and manipulate its components. Soon, they are able to identify levers and wheels and axles on the bicycle. If the teacher had not asked the question, the students would never have integrated the concepts and skills they were studying.

There are other good sources of information that can be used to construct simple and more complex performance tasks. The National Science Teachers Association publishes many excellent books and journals, such as *Children and Science, Science Scope,* and *Science Teacher,* that are full of good ideas and experiments. Newspapers and magazines often contain articles that can be converted into performance tasks.