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Formative Assessment and Science

When teachers are given the statement “When I think of assessment, I think of ...” they almost always complete the statement with the word “testing.” This view of assessment results, in part, from beliefs and practices that stem from text-driven curricula where students study content in a chapter and then are given publisher-provided assessments in the form of multiple-choice, matching, or true/false items related to the content in the chapter. Questions often require students to select a response that was memorized or match terms to definitions. These classroom assessments are used to determine student learning and reward them for learning specific information within a specified time and in a particular way.

Views of classroom assessment are also influenced by the practice of using standardized tests to measure and communicate learning. Levels of performance on summative assessments are communicated through scores or grades that are often more important to students than the knowledge or skills they learned.

NEW WAYS OF THINKING ABOUT ASSESSMENT ■

In recent years the leaders in the assessment field have made serious attempts to explain the significant differences between assessments *of* learning and assessments *for* learning (Black, Harrison, Lee, Marshall, & Wiliam, 2004; Black & Wiliam, 1998; Marzano, 2000; Marzano & Kendall,

2007; Stiggins, 2002; Stiggins & Chappuis, 2006). Understanding this distinction requires a shift from thinking about assessment as a way of determining what students have learned following instruction or as a capstone performance to determine a score or grade to thinking about assessment as part of instruction intended to capture evidence of student learning for purposes of monitoring progress and guiding and improving instruction.

A first step in changing perceptions of assessment requires taking a critical look at assessment as a practice that has, essentially, three different purposes:

1. *Preassessments*: Preassessments are administered to students at the beginning of an instructional unit to identify prior knowledge or misconceptions they may have about a topic. Such information determines a reasonable starting point for instruction.
2. *Formative assessments*: Formative assessments are used throughout instruction to collect evidence of learning for purposes of monitoring progress and guiding instruction.
3. *Summative assessments*: Summative assessments generally take the form of paper-and-pencil tests, capstone performances, or a combination of the two, which follow instruction and are used to:
 - determine how well students “measure up” to a standard
 - compare students to one another and designate positions
 - assign grades

Assessments *for* learning serve a very different purpose than preassessments or summative assessments since their purpose is to provide meaningful feedback to teachers and students about student progress in reaching important learning goals. Scores on assessments for learning are used to inform, not to factor into a grade.

The information provided through formative assessments is used to monitor progress and direct students toward continued learning, relearning, or alternative learning to improve motivation and self-esteem. Reaping the rewards of formative assessment requires not only a shift in practice, but a different way of thinking about effective teaching and learning altogether.

■ GOAL-CENTERED ASSESSMENT

Formative assessment is goal centered; that is, it focuses attention on successful teaching and learning of important learning goals and standards. This approach involves students in the teaching/learning process and offers opportunities for them to take responsibility for learning by setting personal goals and selecting strategies for meaningful learning. Through formative assessment, students compete with themselves rather than with other students.

A comprehensive view of classroom assessment is offered by Stiggins (1994). His principled view of classroom assessment points to the need for classroom teachers to be able to define and assess five kinds of learning goals—knowledge, reasoning, skills, product, and affective goals. This view of

assessment aligns well with the broad range of goals and standards for science education, as well as other areas of the curriculum.

The goal-centered view of assessment challenges teachers to use assessments throughout learning to:

- monitor student progress in conceptual understanding and knowledge and use of skills
- capture evidence of thinking, reasoning, and problem-solving ability
- apply concepts and skills to technology and society through projects, products, and inventions
- provide information about the student's ability to work with others, communicate his or her ideas and understandings, show respect for living things, and demonstrate other dispositions.

Formative assessments capture evidence of student thinking and learning related to important concepts, skills, and habits of mind. Data and information gathered through formative assessments also inform curricular change and professional development needs. A comprehensive definition of formative assessment is offered in Figure 1.1.

RESEARCH SUPPORT FOR FORMATIVE ASSESSMENT

Educational research sends powerful messages to practitioners about what works to enhance student achievement. In their landmark study, Black and Wiliam (1998) surveyed over 580 articles and chapters in an effort to determine if improving formative assessment raises standards. The researchers found overwhelming evidence to support the fact that formative assessment is one of the most powerful tools for promoting effective learning. They also discovered that “improved formative assessment helps low achievers more than other students and so reduces the range of achievement while raising achievement overall” (p. 141).

Black and Wiliam (1998) also showed that achievement gains are greater when teachers involve students in the assessment process. They contend that students need to be trained in self-assessment in order to have a greater understanding of important learning goals and understand what they need to do to achieve success (p. 144). Thus, an essential component of formative assessment is student self-assessment.

Kohn (1999) described self-assessment as teachers and students working together to determine the criteria by which their learning will be assessed and having them do as much of the actual assessment as is practical. He contended that the process is less punitive, gives students control over their education, and provides enormous intellectual benefits (p. 209).

Kohn also cited studies that showed positive results when students were given choices, were involved in decision-making, and felt personally responsible for their learning. Studies reported that students completed more tasks in less time, improved self-esteem and perceived academic competence, and developed higher-level reading skills (pp. 222–223).

Figure 1.1 A Comprehensive View of Formative Assessment

Formative assessment is the practice of using a variety of tools and strategies as part of the instructional process to gather evidence of student thinking and learning from which to make informed decisions about each of these important educational issues.

- Instruction—what we teach, what we do, and how we do it
- Student learning—where they need to go and how to help them get there
- Differentiating instruction—build on student strengths and interests, correct their weaknesses, and provide for students who aren't learning
- Curricular enhancement, modification, and change—concepts to address more thoroughly and experiences to build into the curriculum
- Raising standards of student achievement

As well as . . .

- Professional development needs related to
 - Content knowledge
 - Pedagogy—teaching skills and effective practices
 - Use of technology, resources, and equipment
 - Learning communities
 - Mentoring and coaching

In his study, *How Teaching Matters*, Wenglinsky (2000) linked classroom practices to academic performance in math and science using data from questionnaires to parents, teachers, and over seven thousand eighth-grade students who took the 1996 National Assessment of Educational Progress. Besides identifying characteristics of effective teachers, the study pointed to effective practices, one of which was implementing teacher-developed assessments into their lessons to provide frequent feedback to students about their learning.

Other studies focused on identifying policies and practices that define high-quality teaching and promote learning (Anderson & Stewart, 1997; Black et al., 2004; Ermeling, 2005; Stronge, 2002; Weiss, Pasley, Smith, Baniower, & Heck, 2003). These studies reported that effective teachers encourage interactions among students and between students and teachers and use assessment as a learning tool to provide frequent, constructive feedback to students and to monitor student progress.

Reeves (2008) contended that when grading practices improve, discipline and morale improve as well. He found remarkable changes in one challenging urban high school through focused attention on improved feedback and intervention for students. Positive changes included reduction in course fail-

ures, increase in enrollments in advanced placement courses, decline in suspensions, and a noticeable improvement in teacher morale and school climate.

The instructional power of formative assessment is echoed in the well-known meta-analysis of effective instructional strategies led by Marzano, Pickering, and Pollock (2001), which identified *providing feedback*—a central principle of formative assessment—as one of nine categories of instructional strategies that have statistically significant effects on student achievement.

Marzano and his colleagues offered a quote from researcher John Hattie assaying, “The most powerful single modification that enhances achievement is feedback” (Marzano et al., 2001, p. 96).

Further support for the use of formative assessment in both the learner-centered and knowledge-centered classrooms is provided by the National Research Council: “An important feature of the assessment-centered classroom is assessment that supports learning by providing students with opportunities to review and improve their thinking” (NRC, 2005, p. 16).

The National Science Teachers Association offered a number of research-based position statements that describe the organization’s stand on critical issues related to science education, including the role of assessment. The position statements help to guide administrators and teachers in the design and implementation of a curriculum that addresses important science goals and standards. The position statements can be viewed at <http://www.nsta.org/position>.

CREATING A VISION FOR FORMATIVE ASSESSMENT

There is a body of firm evidence that formative assessment is an essential component of classroom work and that its development can raise standards of achievement. We know of no other way of raising standards for which such a strong prima facie case can be made. Our plea is that national and state policy makers will grasp this opportunity and take the lead in this direction.

—Black & Wiliam, 1998 (p. 147)

In an ideal world, all students would learn and be successful. Educators are well aware that there are many variables that influence student achievement. Yet many of the significant variables that determine what students will learn and how students will learn operate within the classroom setting. With the abundance of research on effective teaching and formative assessment, we know with certainty that the teacher is the key to student learning and that formative assessment is a powerful tool for promoting higher achievement.

In that teaching and assessment are so closely intertwined, the journey toward the use of formative assessment as a tool for increasing student achievement requires us to think critically and thoughtfully about each of these important issues.

- Schoolwide and personal beliefs and practices related to learning and assessment

- Traditional versus student-centered views of teaching and assessment
- Characteristics of effective formative assessment programs

■ EXAMINING BELIEFS AND PRACTICES

Our beliefs strongly influence our practices. There are understandings and misunderstandings associated with the term “assessment.” The ways that teachers view student learning and their beliefs about the purposes of assessment will determine, to a great extent, how they teach and assess in their classrooms.

Clarifying beliefs and practices related to assessment is a first step in creating a vision for the design and implementation of formative assessment tools and strategies in the classroom. Black and Wiliam (1998) contend that the most important difficulties with assessment revolve around three issues: effective learning, a negative impact on learning, and managerial role of assessment. Reflection on these categories provides insight into how beliefs influence practice and help to identify areas in need of change.

An inventory for self-assessment and reflection of issues and practices related to effective learning, impact on learning, and the role of assessment is offered in Figure 1.2. Note the practices that *support* effective teaching and learning are listed under each category.

The chart may be useful for identifying one or more areas for which more information or consideration is needed or for identifying areas needing improvement at the district, school, or classroom level.

■ TRADITIONAL VERSUS STUDENT-CENTERED VIEWS OF ASSESSMENT

Another way to think about assessment is to compare the types of data and information that are collected and communicated in traditional and student-centered classrooms. For this comparison, information about student learning is compared to a photo album. Each way of collecting evidence of what students know and are able to do is one “photograph” in the album.

Two photo albums are shown. Picturing Student Achievement I in Figure 1.3 shows traditional ways that learning is assessed and communicated to students.

Picturing Student Achievement II in Figure 1.4 shows a variety of ways that information about student learning can be collected, communicated to students, and used to inform and guide instruction toward enhanced learning and higher achievement.

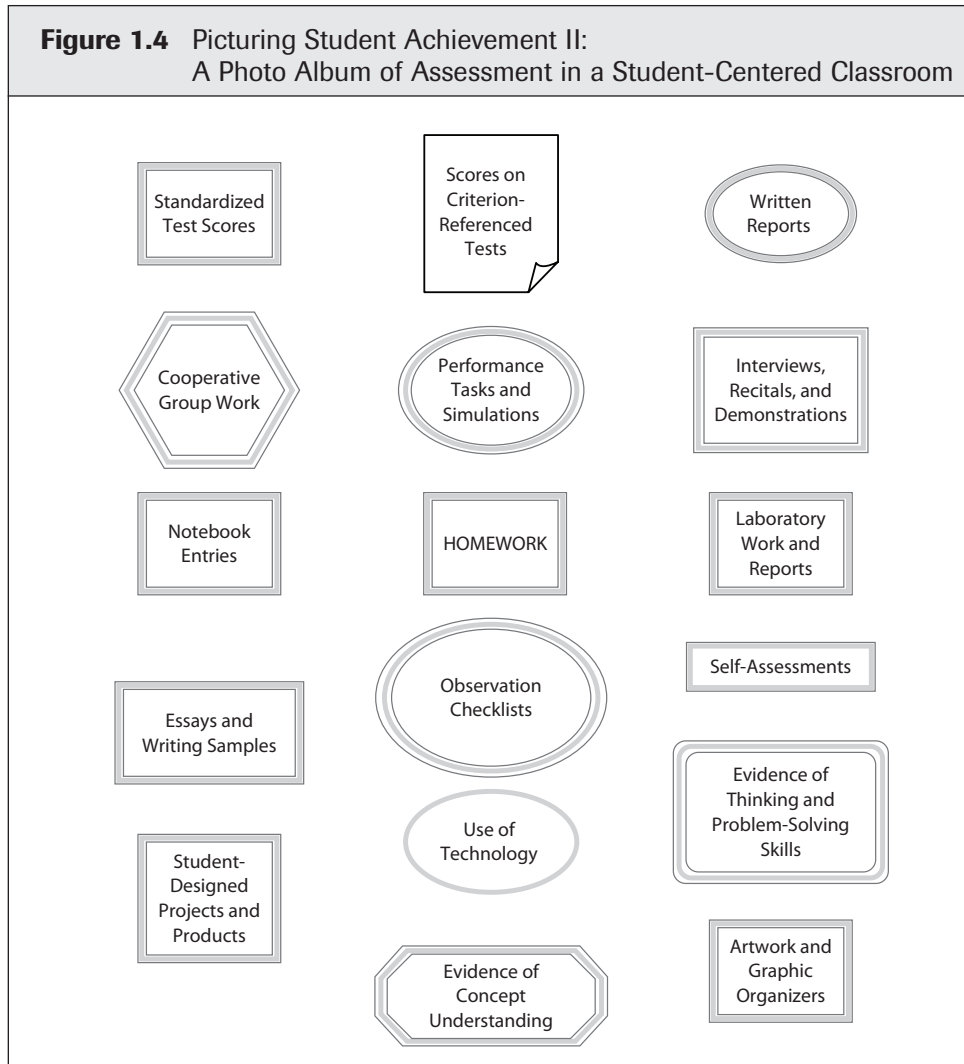
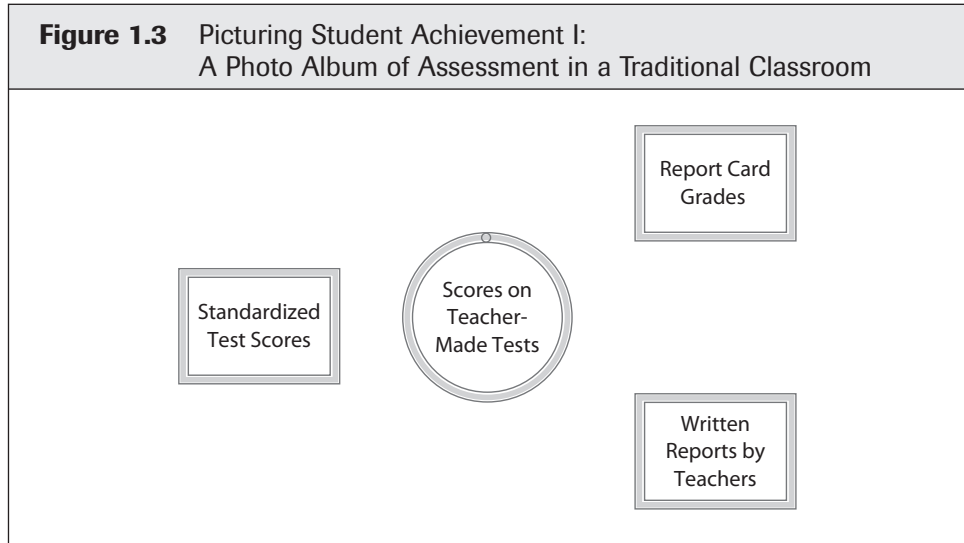
Two albums are provided to show a difference in beliefs about assessment. The first photo album implies that instruction and assessment are separate components where students are “taught” a lesson or series of lessons and then given tests to determine what they have learned. Generally, the test is the final measure of learning for a topic or unit.

Figure 1.2 An Inventory of Issues and Practices			
Issues and Practices Related to Effective Learning	<i>Agree</i>	<i>Disagree</i>	<i>Unsure</i>
Classroom assessments mostly discourage rote and superficial learning and focus on understanding			
Test items and methods of assessing in our school or district are consistent and shared among teachers			
There is consistency and clarity about what concepts and skills individually designed teacher-made tests actually assess			
Most teacher-made tests are criterion-referenced and reflect important goals and standards for the subject area			
Quality of work is emphasized over the quantity of work			
Issues and Practices Related to Impact on Learning	<i>Agree</i>	<i>Disagree</i>	<i>Unsure</i>
Providing useful feedback and giving suggestions for learning are emphasized over giving grades			
Competition with oneself for personal and continuous improvement is valued over competition between students			
Assessment feedback helps low-achieving students gain confidence in their ability to learn			
Issues and Practices Related to the Role of Assessment	<i>Agree</i>	<i>Disagree</i>	<i>Unsure</i>
Feedback to students serves a learning function as opposed to social and managerial functions			
Unlike external tests, teacher-developed assessments help inform teachers and students about strengths and weaknesses			
The analysis of students' work for purposes of motivation and improvement has a higher priority than a collection of grades			
Attention is given to the assessment records from previous grade levels			

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In this view of assessment, student learning is determined and communicated by summative measures such as test scores and written reports identifying strengths and weaknesses that are translated into grades. Grades may also be affected by missing assignments, homework, and behavior.

Test scores alone do not represent the broad range of student learning, nor do they provide varied ways for students to show learning. For example, standardized and teacher-made tests often do not assess concept understanding beyond the knowledge or comprehension levels, process, thinking, or problem-solving skills, habits of mind, or the student's ability to apply concepts to technology and society.



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The second photo album shows a very different view of student learning. This perspective shows that while scores on standardized and criterion-referenced tests and written reports may not go away as measures of achievement, a more complete description of learning can be compiled and communicated to students and others through a variety of formative assessments.

In this view of assessment, student work, demonstrations of learning, self-assessments, performances, and so forth are regarded as evidence of the extent to which learning goals were achieved. The assessment tools and strategies that expand this perspective of learning are embedded in instruction and used throughout the instructional process to inform students of their progress and to guide and enhance learning.

FORMATIVE ASSESSMENT AS “AUTHENTIC” ASSESSMENT

“Authentic assessment” is a term used by Wiggins in the early 1990s to describe assessments that are aligned with important learning goals and standards and are worth mastering. Authentic assessments emulate the standards that are set for those in professional fields and provide realistic contexts. Formative classroom assessments are authentic when they

- align with important goals and standards in the eight content categories of science
- are meaningful, purposeful, and instructional
- provide multiple and varied ways for students to show what they know and are able to do
- capture student thinking and mental constructs as well as their misunderstandings
- are thought-provoking and challenging
- provide opportunities for students to self-assess and take responsibility for learning

When built into the instructional plan, formative assessments provide immediate feedback about student learning without taking valuable time from instruction because they are part of instruction. For example, during an investigation, a teacher might use a checklist to record observations related to the safe and correct handling and use of equipment and the ability of students to work cooperatively in a group. Notebook entries may show that students have misinterpreted directions or misunderstood a concept or that students are on task and progressing well through the task. The key to successful formative assessment lies with the use of multiple and varied ways to capture evidence of thinking and learning that naturally flow from well-defined goals and rich and meaningful contexts for instruction.

■ CLEAR TARGETS FOR INSTRUCTION AND ASSESSMENT

Children develop theories about the world and how it works early in life. As learners, they continually link new information to prior knowledge and restructure their frames of thought. If we assess what we value, assessment tools must be appropriate for gathering the types of information about student learning that are aligned with clear instructional goals. Goals that are ill defined, taken for granted, assumed, or mistaken for instructional activities are seldom reached.

Goals for School Science

National and state leaders emphasize the need to view science as more than a set of accumulated facts and theories. The National Science Education Standards identified the goals for school science as educating students who are able to

- experience the richness and excitement of knowing about and understanding the natural world
- use appropriate scientific processes and principles in making personal decisions
- engage intelligently in public discourse and debate about matters of scientific and technological concern
- increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers (NRC, 1996, p. 13)

Scientific Literacy

Scientific literacy is the goal of science education, but what does scientific literacy actually look like? Scientific literacy may be operationally defined by observing the behaviors of natural scientists, social scientists, behavioral scientists, and similar professional and amateur scientists.

Scientists by nature explore, investigate, and experiment to discover and uncover the mysteries of the universe and answer questions related to natural and social worlds. Although their methods are somewhat varied, they do have characteristics in common. There are similarities in the ways scientists formulate questions, generate hypotheses, make observations, collect and interpret data, check and recheck their findings, use what they learn to change their views of knowledge, ask new questions, and seek more answers.

Not surprisingly, these processes are common to problem solving in any discipline and to learning in general. The problems and issues faced by citizens in daily life are not unlike those faced by professionals and require practice of the same processes and thinking skills used by scientists, mathematicians, historians, artists, musicians, politicians, and so forth, to solve problems in their respective disciplines.

The National Science Education Standards (NRC, 1996) described a scientifically literate person as one who

- can ask, find, or determine answers to questions derived from curiosity about everyday experiences
- has the ability to describe, explain, and predict natural phenomena
- is able to read, with understanding, articles about science in the popular press and to engage in social conversation about the validity of the conclusions
- can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed
- is able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it
- has the ability to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately
- is able to display scientific literacy by appropriately using technical terms and by applying concepts and processes (p. 22)

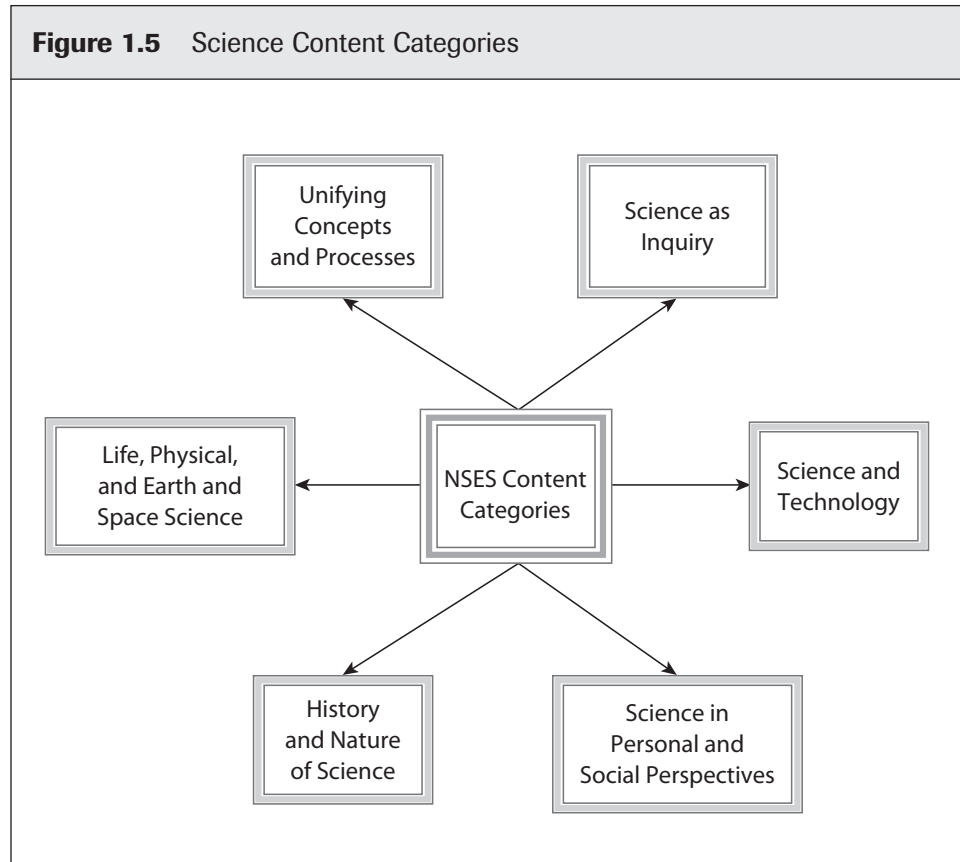
Science Content Categories

Underlying the characteristics of the scientifically literate citizen is a strong knowledge base, but as one can see from the description, the knowledge base alone is not the end product of science education. The instructional goals that are deemed most worthy of student learning in science are derived from the national and state standards projects that address the content categories identified in the National Science Education Standards (Figure 1.5) and are reflected in the Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1993). It is critical for teachers to have a clear understanding of these important learning goals in order to guide students toward their mastery.

Steeped within this multidimensional view of science are opportunities for students to develop content-related skills and habits of mind, as well as other important twenty-first-century knowledge and learning skills such as

- information and media literacy
- communication skills
- complex thinking and reasoning
- problem solving, creativity
- interpersonal and collaborative skills
- self-direction, accountability and adaptability, and social responsibility. (Partnership for 21st Century Skills, <http://www.21stcenturyskills.org>)

Science is an active process. If classroom science is to provide opportunities for students to learn and practice science as it exists throughout the scientific community, it must closely resemble the experiences and types of thinking commonly used by scientists in the field and laboratories of the world. The disciplines of science with their concepts and principles, topics, themes, problems, and issues offer the contexts through which knowledge and problem-solving skills, as well as skills of lifelong learning, can be



developed. National and state standards projects provide the focus for science curricula. Programs rich with developmentally appropriate inquiry-based experiences provide the basis for learning important concepts and developing skills and valued habits of mind.

Scientific Habits of Mind

Another important consideration on the road to the development of the well-informed citizenry is the development of habits of mind. This term refers to values and attitudes often called dispositions plus mathematical, logical, problem-solving and thinking skills, and communication and critical response skills valued by the scientific community and by society in general. Scientists exhibit these values, attitudes, and skills throughout their professional work and in their personal lives. Figure 1.6 shows a list of values, attitudes, and skills underlying science gleaned from national standards projects and the literature that are collectively referred to as habits of mind.

These qualities and characteristics described in the habits of mind can be developed in the science classroom. Teachers who are enthusiastic and model desired attitudes, values, and skills for lifelong learning strongly influence the attitudes and behaviors developed by students. When students are given opportunities to engage in inquiry-based science, they are able to develop and demonstrate the habits of mind.

Creating a vision for formative assessment as an approach to enhancing student learning in science requires an understanding of standards-

Figure 1.6 Scientific Habits of Mind	
<i>Habits of Mind</i>	<i>Descriptions</i>
Honesty	Truthful and trustworthy; free from deceit; exhibits accuracy in reporting data or information
Curiosity and a Desire for Knowledge	An innate or developed desire for knowing and understanding the world
Cooperation	A shared discussion of ideas, theories, and techniques at the local, state, national, and international levels
Having Confidence in and Relying on Data	Respecting evidence, which also implies the testing and retesting of ideas and monitoring of one's own thinking processes
Comfort With Ambiguity	The results of science are always tentative; testing and retesting provide more confidence in one's conclusions; ambiguity gives rise to new problems and questions
Balancing Open-Mindedness With Skepticism	Being open to new theories and willingness to disregard current ones; respecting new ideas and proposals, but remaining skeptical until evidence is offered
Respect for Living Things	All living things deserve human care both in the lab and in the field; attitudes and behaviors in the handling and care of live organisms says much about our value systems as human beings
Willingness to Modify Explanations	Newly acquired data or reinterpretations of existing data may require one to modify explanations for phenomena and events; willingness to rethink conclusions is often one of science's and science learning's most difficult personal decisions
Respecting and Trusting the Thinking Process	Science is an active process defined by patterns of reasoning that lead to theory building and theory testing; trust in the process is an essential element
Computation and Estimation	Ability to solve mathematical problems in real-world situations; the ability to explain how to calculate an answer before carrying it out; ability to express arguments quantitatively
Manipulation and Observation	Using first-hand, sensory experiences and tools of technology for learning and problem solving
Critical-Response Skills	Ability to separate "sense" from "nonsense" when confronted with claims put forth by experts and non-experts about products, systems or devices, and health and welfare; ability to make judgments based on the character of an assertion

related instructional goals as well as an understanding of the purpose, strategies, and tools of formative assessment. The following chapters are intended to provide greater insight into ways formative assessment can be used to enhance learning in science.