

NBPTS Adolescence and Young Adulthood Science STANDARDS

Second Edition



for teachers of students ages 14–18+

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Adolescence and Young Adulthood/Science STANDARDS

(for teachers of students ages 14–18+)

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Preface	V
Introduction	1
Overview	7
The Standards	9
<u>Preparing the Way for Productive Student Learning</u>	
I. Understanding Students	9
II. Understanding Science	13
III. Understanding Science Teaching	21
<u>Establishing a Favorable Context for Student Learning</u>	
IV. Engaging the Science Learner	27
V. Sustaining a Learning Environment	31
VI. Promoting Diversity, Equity, and Fairness	35
<u>Advancing Student Learning</u>	
VII. Fostering Science Inquiry	39
VIII. Making Connections in Science	43
IX. Assessing for Results	47
<u>Promoting Professional Development and Outreach</u>	
X. Reflecting on Teaching and Learning	51
XI. Developing Collegiality and Leadership	55
XII. Connecting with Families and the Community	59
Epilogue	63
Standards Committees	65
Acknowledgments	69

The world-class schools the United States requires cannot exist without a world-class teaching force; the two go hand in hand. Many accomplished teachers already work in the nation's schools, but their knowledge and skills are often unacknowledged and underutilized. Delineating outstanding practice and recognizing those who achieve it are important first steps in shaping the kind of teaching profession the nation needs. This is the core challenge embraced by the National Board for Professional Teaching Standards® (NBPTS). Founded in 1987 with a broad base of support from governors, teacher union and school board leaders, school administrators, college and university officials, business executives, foundations, and concerned citizens, NBPTS is an independent, nonprofit, nonpartisan, and nongovernmental organization governed by a board of directors, the majority of whom are classroom teachers. Committed to basic reform in education, NBPTS recognizes that teaching is at the heart of education and, further, that the single most important action the nation can take to improve schools is to strengthen teaching.

The National Board's mission is to advance the quality of teaching and learning by:

- maintaining high and rigorous standards for what accomplished teachers should know and be able to do;
- providing a national voluntary system certifying teachers who meet these standards; and
- advocating related education reforms to integrate National Board Certification® in American education and to capitalize on the expertise of National Board Certified Teachers®.

Dedication to this mission is elevating the teaching profession, educating the public about the demands and complexity of accomplished teaching practice, and making teaching a more attractive profession for talented college graduates with many other promising career options.

National Board Certification is more than a system for recognizing and rewarding accomplished teachers. It offers an opportunity to guide the continuing growth and development of the teaching profession. Together with other reforms, National Board Certification is a catalyst for significant change in the teaching profession and in education.

The Philosophical Context

The standards presented here lay the foundation for the Adolescence and Young Adulthood/Science certificate. They represent a professional consensus on the aspects of practice that distinguish accomplished teachers. Cast in terms of actions that teachers take to advance student achievement, these standards also incorporate the essential knowledge, skills, dispositions, and commitments that allow teachers to practice at a high level. Like all NBPTS Standards, this standards document is grounded philosophically in the NBPTS policy statement *What Teachers Should Know and Be Able to Do*. That statement identifies five core propositions.

1) Teachers are committed to students and their learning.

Accomplished teachers are dedicated to making knowledge accessible to all students. They act on the belief that all students can learn. They treat students equitably, recognizing the individual differences that distinguish their students from one another and taking account of these differences in their practice. They adjust their practice, as appropriate, on the basis of observation and knowledge of their students' interests, abilities, skills, knowledge, family circumstances, and peer relationships.

Accomplished teachers understand how students develop and learn. They incorporate the prevailing theories of cognition and intelligence in their practice. They are aware of the influence of context and culture on behavior. They develop students' cognitive capacity and respect for learning. Equally important, they foster students' self-esteem; motivation; character; sense of civic responsibility; and respect for individual, cultural, religious, and racial differences.

2) Teachers know the subjects they teach and how to teach those subjects to students.

Accomplished teachers have a rich understanding of the subject(s) they teach and appreciate how knowledge in their subjects is created, organized, linked to other disciplines, and applied to real-world settings. While faithfully representing the collective wisdom of our culture and upholding the value of disciplinary knowledge, they also develop the critical and analytical capacities of their students.

Accomplished teachers command specialized knowledge of how to convey subject matter to students. They are aware of the preconceptions and background knowledge that students typically bring to each subject and of strategies and instructional resources that can be of assistance. Their instructional repertoire allows them to create multiple paths to learning the subjects they teach, and they are adept at teaching students how to pose and solve challenging problems.

3) Teachers are responsible for managing and monitoring student learning.

Accomplished teachers create, enrich, maintain, and alter instructional settings to capture and sustain the interest of their students. They make the most effective use of time in their instruction. They are adept at engaging students and adults to assist their teaching and at making use of their colleagues' knowledge and expertise to complement their own.

Accomplished teachers command a range of instructional techniques and know when to employ them. They are devoted to high-quality practice and know how to offer each student the opportunity to succeed.

Accomplished teachers know how to engage groups of students to ensure a disciplined learning environment and how to organize instruction so as to meet the schools' goals for students. They are adept at setting norms of social interaction among students and between students and teachers. They understand how to motivate students to learn and how to maintain their interest even in the face of temporary setbacks.

Accomplished teachers can assess the progress of individual students as well as the progress of the class as a whole. They employ multiple methods for assessing student growth and understanding and can clearly explain student performance to students, parents, and administrators.

4) Teachers think systematically about their practice and learn from experience.

Accomplished teachers are models of educated persons, exemplifying the virtues they seek to inspire in students—curiosity, tolerance, honesty, fairness, respect for diversity, and appreciation of cultural differences. They demonstrate capacities that are prerequisites for intellectual growth—the ability to reason, take multiple perspectives, be creative and take risks, and experiment and solve problems.

Accomplished teachers draw on their knowledge of human development, subject matter, and instruction, and their understanding of their students to make principled judgments about sound practice. Their decisions are grounded not only in the literature of their fields, but also in their experience. They engage in lifelong learning, which they seek to encourage in their students.

Striving to strengthen their teaching, accomplished teachers examine their practice critically; expand their repertoire; deepen their knowledge; sharpen their judgment; and adapt their teaching to new findings, ideas, and theories.

5) Teachers are members of learning communities.

Accomplished teachers contribute to the effectiveness of the school by working collaboratively with other professionals on instructional policy, curriculum development, and staff development. They can evaluate school progress and the allocation of school resources in light of their understanding of state and local educational objectives. They are knowledgeable about specialized school and community resources that can be engaged for their students' benefit and are skilled at employing such resources as needed.

Accomplished teachers find ways to work collaboratively and creatively with parents, engaging them productively in the work of the school.

The Certification Framework

Using the Five Core Propositions as a springboard, NBPTS sets standards and offers National Board Certification in nearly 30 fields. These fields are defined by the developmental level of the students and the subject or subjects being taught. The first descriptor represents the four overlapping student developmental levels:

- Early Childhood, ages 3–8;
- Middle Childhood, ages 7–12;
- Early Adolescence, ages 11–15; and
- Adolescence and Young Adulthood, ages 14–18+.

The second descriptor indicates the substantive focus of a teacher's practice. Teachers may select either a subject-specific or a generalist certificate at a particular developmental level. Subject-specific certificates are designed for teachers who emphasize a single subject area in their teaching (e.g., Early Adolescence/English Language Arts, Adolescence and Young Adulthood/Mathematics); generalist certificates are designed for teachers who develop student skills and knowledge across the curriculum (e.g., Early

Childhood/Generalist, Middle Childhood/Generalist). For some subject-specific certificates, developmental levels are joined together to recognize the commonalities in teaching students at those developmental levels (e.g., Early and Middle Childhood/Art).

Standards and Assessment Development

Following a nationwide search for outstanding educators, a standards committee is appointed for each field. The committees are generally made up of 15 members who are broadly representative of accomplished professionals in their fields. A majority of committee members are teachers regularly engaged in teaching students in the field in question; other members are typically professors, experts in child development, teacher educators, and other professionals in the relevant discipline. The standards committees develop the specific standards for each field, which are then disseminated widely for public critique and comment and subsequently revised as necessary before adoption by the NBPTS Board of Directors. Periodically, standards are updated so that they remain dynamic documents, responsive to changes in the field.

Determining whether or not candidates meet the standards requires performance-based assessment methods that are fair, valid, and reliable and that ask teachers to demonstrate principled, professional judgments in a variety of situations. A testing contractor specializing in assessment development works with standards committee members, teacher assessment development teams, and members of the NBPTS staff to develop assessment exercises and pilot test them with teachers active in each certificate field. The assessment process involves two primary activities: (1) the compilation of a portfolio of teaching practice over a period of time and (2) the demonstration of content knowledge through assessment center exercises. Teachers prepare their portfolios by videotaping their teaching, gathering student learning products and other teaching artifacts, and providing detailed analyses of their practice. At the assessment center, teachers answer questions that relate primarily to content knowledge specific to their fields.

The portfolio is designed to capture teaching in real-time, real-life settings, thus allowing trained assessors from the field in question to examine how teachers translate knowledge and theory into practice. It also yields the most valued evidence NBPTS collects—videotapes of practice and samples of student work. The videotapes and student work are accompanied by commentaries on the goals and purposes of instruction, the effectiveness of the practice, teachers' reflections on what occurred, and their rationales for the professional judgments they made. In addition, the portfolio allows candidates to document their accomplishments in contributing to the advancement of the profession and the improvement of schooling—whether at the local, state, or national level—and to document their ability to work constructively with their students' families.

Teachers report that the portfolio is a professional development vehicle of considerable power, in part because it challenges the historic isolation of teachers from their peers. It accomplishes this by actively encouraging candidates to seek the advice and counsel of their professional colleagues—whether across the hall or across the country—as they build their portfolios. It also requires teachers to examine the underlying assumptions of their practice and the results of their efforts in critical but healthy ways. This emphasis on reflection is highly valued by teachers who go through the process of National Board Certification.

The assessment center exercises are designed to complement the portfolio. They validate that the knowledge and skills exhibited in the portfolio are, in fact, accurate reflections of what candidates know and can do, and they give candidates an opportunity to demonstrate knowledge and skills not sampled in the portfolio because of the candidate's specific teaching assignment. For example, high school science teachers assigned to teach only physics in a given year might have difficulty demonstrating in their portfolio a broad knowledge of biology. Given that the NBPTS Standards for science teachers place a high value on such capabilities, another strategy for data collection is necessary. The assessment center exercises fill this gap and otherwise augment the portfolio. Each candidate's work is examined by trained assessors who teach in the certificate field.

The National Board for Professional Teaching Standards believes that a valid assessment of accomplished practice must allow for the variety of forms sound practice takes. It must also sample the range of content knowledge that teachers possess and must provide appropriate contexts for assessments of teaching knowledge and skill. Teaching is not just about knowing things; it is about the use of knowledge—knowledge of learners and of learning, of schools and of subjects—in the service of helping students grow and develop. Consequently, NBPTS believes that the most valid teacher assessment processes engage candidates in the activities of teaching—activities that require the display and use of teaching knowledge and skill and that allow teachers the opportunity to explain and justify their actions.

In its assessment development work, NBPTS uses technology for assessment when appropriate; ensures broad representation of the diversity that exists within the profession; engages pertinent disciplinary and specialty associations at key points in the process; collaborates closely with appropriate state agencies, academic institutions, and independent research and education organizations; establishes procedures to detect and eliminate instances of external and internal bias with respect to age, gender, and racial and ethnic background of teacher-candidates; and selects the method exhibiting the least adverse impact when given a choice among equally valid assessments.

Once an assessment has been thoroughly tested and found to meet NBPTS requirements for validity, reliability, and fairness, eligible teachers may apply for National Board Certification. To be eligible, a teacher must hold a baccalaureate degree from an accredited institution; have a minimum of three years' teaching experience at the early childhood, elementary school, middle school, or high school level; and have held a valid state teaching license for those three years or, where a license is not required, have taught in schools recognized and approved to operate by the state.

Strengthening Teaching and Improving Learning

The National Board's system of standards and certification is commanding the respect of the profession and the public, thereby making a difference in how communities and policymakers view teachers, how teachers view themselves, and how teachers improve their practice throughout their careers. National Board Certification has yielded such results in part because it has forged a national consensus on the characteristics of accomplished teaching practice in each field. The traditional conversation about teacher competence has focused on beginning teachers. The National Board for Professional Teaching Standards has helped broaden this conversation to span the entire career of teachers.

Developing standards of accomplished practice helps to elevate the teaching profession as the standards make public the knowledge, skills, and dispositions of accomplished teachers. However, making such standards the basis for National Board Certification promises much more. Because National Board Certification identifies accomplished teachers in a fair and trustworthy manner, it can offer career paths for teachers that will make use of their knowledge, wisdom, and expertise; give accomplished practitioners the opportunity to achieve greater status, authority, and compensation; and accelerate efforts to build more successful school organizations and structures.

By holding accomplished teachers to high and rigorous standards, National Board Certification encourages change along several key fronts:

- changing what it means to have a career in teaching by recognizing and rewarding accomplished teachers and by making it possible for teachers to advance in responsibility, status, and compensation without having to leave the classroom;
- changing the culture of teaching by accelerating growth in the knowledge base of teaching, by placing real value on professional judgment and accomplished practice in all its various manifestations, and by encouraging teachers to search for new knowledge and better practice through a steady regimen of collaboration and reflection with peers and others;
- changing the way schools are organized and managed by creating a vehicle that facilitates the establishment of unique teacher positions, providing accomplished teachers with greater authority and autonomy in making instructional decisions and greater responsibility for sharing their expertise to strengthen the practice of others;
- changing the nature of teacher preparation and ongoing professional development by laying a standards-based foundation for a fully articulated career development path that begins with prospective teachers and leads to accomplished teachers; and
- changing the way school districts think about hiring and compensating teachers by encouraging administrators and school boards to reward excellence in teaching by seeking to hire accomplished teachers.

Although National Board Certification has been designed with the entire country in mind, each state and locality decides for itself how best to encourage teachers to achieve National Board Certification and how best to take advantage of the expertise of the National Board Certified Teachers in their midst. Across the country, legislation has been enacted that supports National Board Certification, including allocations of funds to pay for the certification fee for teachers, release time for candidates to work on their portfolios and prepare for the assessment center exercises, and salary supplements for teachers who achieve National Board Certification. Incentives for National Board Certification exist at the state or local level in all 50 states and in the District of Columbia.

As this support at the state and local levels suggests, National Board Certification is recognized throughout the nation as a rich professional development experience. Because National Board Certification provides states and localities with a way to structure teachers' roles and responsibilities more effectively and to allow schools to benefit from the wisdom of their strongest teachers, National Board Certification is a strong component of education reform in the United States.

At the daybreak of this new century and millennium...the future well-being of our nation and people depends not just on how well we educate our children generally, but on how well we educate them in mathematics and science specifically.... The most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching.¹

Science education is being reshaped in the United States. The changes have been partly fueled by a long-standing conviction shared by social planners and the members of the Glenn Commission: This nation's economic and political future depends heavily on how well the nation's youth learn science and technology. The nation and its children deserve and must have science teachers who know their students, know their subject, and are passionate about both. All teachers of science must rise to the same challenge and meet the same goal: to provide a rich and robust science education so all students leave their classrooms—and formal education—knowledgeable and enthusiastic about science and ready to take their places as productive citizens.

1. The National Commission on Mathematics and Science Teaching for the 21st Century (Glenn Commission). *Before It's Too Late* (Washington, D.C.: The National Commission on Mathematics and Science Teaching for the 21st Century, 2000).

The Challenge Before the Science Education Community

Research shows that children who receive quality science instruction in the elementary years enjoy and benefit from the experience. By the middle grades, however, too many youngsters display a negative attitude toward science. Science performances begin to lag, especially among many female and minority students. To be sure, a segment of high school students receives a superb preparation in the sciences as measured against any standard of excellence in the world. Far too many young people discover, however, that by the time they reach high school—and without having made a conscious decision in the matter—they effectively have been consigned to a minimal-science, low-opportunity learning track.

This state of affairs is unacceptable for many reasons, not the least of which is singularly pragmatic. The U.S. Department of Commerce has forecast that women and members of minority groups will soon make up almost two-thirds of the new workforce in the United States. More jobs than ever before—and a higher proportion of the best-paying ones—will require a functional knowledge of science and mathematics. Clearly, then, looked at as a question of opening the doors of opportunity for every student or as a matter of national self-interest, schools must ensure that all students have the opportunity to become intellectually competent and confident in science.

Beyond economic considerations are other compelling reasons for aspiring to this inclusive goal. When taught by accomplished teachers, science stimulates curiosity about the world. Science makes students aware of commonalities, while expanding their understanding and appreciation of diversity. Students taught well in science develop a fascination for life in all its forms, which contributes to their desire to learn about the world and to respect its makeup as well as its inhabitants. Students who understand multiple methods and philosophies of science develop a deeply satisfying approach to looking at the world and helping shape it, one that will reward their efforts for the rest of their lives. They learn that the pursuit of science is enjoyable in its own right and that this pursuit

helps them develop invaluable cognitive processes of reasoning and analysis. They also learn that science belongs to everyone. The drive to understand the natural environment and thereby gain a measure of control over it is universal and exhibited by peoples from all ethnic backgrounds, eras, and civilizations through recorded time. Science contributes to students' respect for their own culture as well as for a common heritage. Science can help students explore in their everyday environs the full measure of their own humanity and help them play a responsible part in society. In a time of increasingly complex debates over public policy and the uses of technology, a knowledge of science and a commitment to the enjoyment of science have become essential ingredients of good citizenship.

Moving Toward a New Vision of Science Education

Certainly, improving science education will require a great deal of work by all members of the education community. The curricular reforms in science that followed the launching of Sputnik I in 1957 were aimed, for the most part, at guaranteeing that the nation's education system would produce a cadre of talented young scientists sufficient to meet the nation's needs. Now, however, the consensus is that the commitment of schools to science education must be far more inclusive and ensure that all students reach the vital goal of becoming scientifically literate.

What might that science literacy entail? Two national science organizations—the American Association for the Advancement of Science through its Project 2061 and the National Research Council through its development of *National Science Education Standards*²—continue to be engaged in major reform initiatives in science education to improve the science literacy of all students. Both have adopted the same overriding goal: All students will be scientifically literate by the time they graduate from high school. As defined in their documents, a scientifically literate person is one who has a strong knowledge of (1) the nature of science, including a grasp of the various inquiry processes that scientists use to discover new knowledge as well as of the attitudes and habits of mind—honesty, skepticism, openness to new ideas, and curiosity—essential to an objective investigator; (2) the most important concepts from the body of scientific knowledge; and (3) the human contexts of science, including a familiarity with the history of its development and its reciprocal relationship with mathematics and technology, and their mutual economic, political, and cultural impacts on society. Most important, a scientifically literate person not only knows about these various aspects of science but also uses them in ethical decision making and participation in civic life.

Science literacy for all students is an attainable goal; reaching it, however, will require continued progress. In particular, science education in the United States has been criticized for a tendency to overburden students with the mastery of facts and technical terminology at the expense of having them actively doing science—observing phenomena, asking questions, making predictions, devising tests of their ideas, recording data accurately, reaching conclusions, and clearly communicating results. The philosophy that underlies this document is based on several assumptions about how children learn, all supported by a growing body of research. One is that students learn best when actively engaged, physically and mentally, through experience-based activities in science accompanied by regular opportunities to think

2. National Research Council. *National Science Education Standards* (Washington, D.C.: National Academy Press, 1995).

about the significance of what they have been seeing and doing and to develop deep understanding of key scientific concepts. A second is that students benefit immensely when they are helped to explore science concepts that derive from or connect with their everyday experiences in the world. A third is that students' insights are enriched when they have opportunities to share and test their ideas with the larger team of investigators in the classroom and beyond.

Addressing Diversity

Accomplished science teachers accept the challenge of making science accessible to all their students, regardless of race, ethnicity, language, socioeconomic background, religion, family background, gender, and all the other factors of culture and heritage that give each classroom vibrancy. They respect what their students bring into the classroom and use their knowledge of their students' cultures to make science interesting. And they do so while ensuring that all their students engage in sophisticated, in-depth learning and while holding their students to high standards. Fairness and equity are hallmarks of their classrooms.

While diversity brings rewards, it also brings challenges, one of which is literacy. Many students who arrive in the classrooms of accomplished teachers have limited skills in English. Traditionally, these students were thought of as learners of English as a new language. However, accomplished teachers are increasingly aware that even students whose first language is English may have language deficits that impede their ability to learn well. The type of English that serves students well on the streets and in their homes is often insufficient for success in the classroom. Accomplished teachers recognize that they often must explicitly teach academic discourse—the syntactical rules and lexicon necessary for learning in a school setting—as well as the language specific to the discipline of science.

Developing High and Rigorous Standards for Accomplished Teaching

In 1992, a committee of Adolescence and Young Adulthood/Science teachers and other educators with expertise in this field began the process of developing advanced professional standards for teachers of students ages 14 to 18+. The Adolescence and Young Adulthood/Science Standards Committee was charged with translating the Five Core Propositions of the National Board for Professional Teaching Standards into a standards document that defines outstanding teaching in this field.

In 2002, a committee comprising original committee members and a new group of educators (including National Board Certified Teachers) was convened to examine and update as necessary the published *Adolescence and Young Adulthood/Science Standards*. This second edition of the standards is the result of the committee's deliberations at meetings and their input into working drafts of the standards.

This NBPTS Standards document describes in observable form what accomplished teachers should know and be able to do. The standards are meant to reflect a professional consensus at this point about the essential aspects of accomplished practice. The deliberations of the Adolescence and Young Adulthood/Science Standards Committee were informed by various national and state initiatives on student and teacher standards that have been operating concurrently with the development of NBPTS Standards. As the understanding of teaching and learning continues to evolve, *Adolescence and Young Adulthood/Science Standards* will be updated again.

An essential tension of describing accomplished practice concerns the difference between the analysis and the practice of teaching. The former tends to fragment the profession into any number of discrete duties, such as designing learning activities, providing quality explanation, modeling, managing the classroom, and monitoring student progress. Teaching as it actually occurs, however, is a seamless activity.

Everything an accomplished teacher knows through study, research, and experience is brought to bear daily in the classroom through innumerable decisions that shape learning. It frequently requires balancing the demands of several important educational goals. It depends on accurate observations of particular students and settings. And it is subject to revision on the basis of continuing developments in the classroom. The professional judgments that accomplished teachers make also reflect a certain improvisational artistry.

The paradox, then, is that any attempt to write standards that dissect what accomplished teachers know and are able to do will, to a certain extent, misrepresent the holistic nature of how teaching actually takes place. Nevertheless, the fact remains: Certain identifiable commonalities characterize the accomplished practice of teachers. The 12 standards that follow are designed to capture the craft, artistry, proficiencies, and understandings—both deep and broad—that contribute to the complex work that is accomplished teaching.

The Standards Format

Accomplished teaching appears in many different forms, and it should be acknowledged at the outset that these specific standards are not the only way that accomplished teaching could have been described. No linearity, atomization, or hierarchy is implied in this vision of accomplished teaching, nor is each standard of equal weight. Rather, the standards are presented as aspects of teaching that are analytically separable for the purposes of this standards document but that are not discrete when they appear in practice.

The report follows a two-part format for each of the 12 standards:

- I. *Standard Statement***—This is a succinct statement of one vital aspect of the practice of the accomplished Adolescence and Young Adulthood/Science teacher. Each standard is expressed in terms of observable teacher actions that have an impact on students.
- II. *Elaboration***—This passage provides a context for the standard, along with an explanation of what teachers need to know, value, and do if they are to fulfill the standard. The elaboration includes descriptions of teacher dispositions toward students, their distinctive roles and responsibilities, and their stances on a range of ethical and intellectual issues that regularly confront them.

The 12 standards have been organized around the nexus of education—student learning. They are divided into four categories: (1) teacher actions that prepare the way for productive student learning; (2) teacher actions that establish a favorable context for student learning; (3) teacher actions that directly advance student learning in the classroom; and (4) teacher actions that indirectly support student learning through long-range initiatives conducted, for the most part, outside the classroom. Such a “roadmap” for reading the document should not be taken too literally, because, as noted above, accomplished teaching is a holistic act in which the many facets of practice come together to advance student learning.

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(for teachers of students ages 14–18+)

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OVERVIEW

The National Board for Professional Teaching Standards has developed the following 12 standards of accomplished practice for Adolescence and Young Adulthood/Science teachers. The standards have been ordered as they have to facilitate understanding,

not to assign priorities. They each describe an important facet of accomplished teaching; they often occur concurrently because of the seamless quality of teaching. The standards serve as the basis for National Board Certification in this field.

Preparing the Way for Productive Student Learning

I. Understanding Students (p. 9)

Accomplished Adolescence and Young Adulthood/Science teachers know how students learn, know their students as individuals, and determine students' understandings of science as well as their individual learning backgrounds.

II. Understanding Science (p. 13)

Accomplished Adolescence and Young Adulthood/Science teachers have a broad and current knowledge of science and science education, along with in-depth knowledge of one of the subfields of science, which they use to set important and appropriate learning goals.

III. Understanding Science Teaching (p. 21)

Accomplished Adolescence and Young Adulthood/Science teachers employ a deliberately sequenced variety of research-driven instructional strategies and select, adapt, and create instructional resources to support active student exploration and understanding of science.

Establishing a Favorable Context for Student Learning

IV. Engaging the Science Learner (p. 27)

Accomplished Adolescence and Young Adulthood/Science teachers spark student interest in science and promote active and sustained learning, so all students achieve meaningful and demonstrable growth toward learning goals.

V. Sustaining a Learning Environment (p. 31)

Accomplished Adolescence and Young Adulthood/Science teachers create safe, supportive, and stimulating learning environments that foster high expectations for each student's successful science learning and in which students experience and incorporate the values inherent in the practice of science.

VI. Promoting Diversity, Equity, and Fairness (p. 35)

Accomplished Adolescence and Young Adulthood/Science teachers ensure that all students, including those from groups that have historically not been encouraged to enter the world of science and that experience ongoing barriers, succeed in the study of science and understand the importance and relevance of science.

Advancing Student Learning

VII. Fostering Science Inquiry (p. 39)

Accomplished Adolescence and Young Adulthood/Science teachers engage students in active exploration to develop the mental operations and habits of mind that are essential to advancing strong content knowledge and scientific literacy.

VIII. Making Connections in Science (p. 43)

Accomplished Adolescence and Young Adulthood/Science teachers create opportunities for students to examine the human contexts of science, including its history, reciprocal relationship with technology, ties to mathematics, and impacts on society, so that students make connections across the disciplines of science, among other subject areas, and in their lives.

IX. Assessing for Results (p. 47)

Accomplished Adolescence and Young Adulthood/Science teachers employ multiple, ongoing methods that are fair and accurate to analyze the progress of individual students in light of well-defined learning goals, and their students achieve meaningful and demonstrable gains in the learning of science. Teachers clearly communicate these gains to appropriate audiences.

Promoting Professional Development and Outreach

X. Reflecting on Teaching and Learning (p. 51)

Accomplished Adolescence and Young Adulthood/Science teachers continually analyze, evaluate, and strengthen their practice to improve the quality of their students' learning experiences.

XI. Developing Collegiality and Leadership (p. 55)

Accomplished Adolescence and Young Adulthood/Science teachers contribute to the quality of the practice of their colleagues, to the instructional program of the school, and to the work of the larger professional community.

XII. Connecting with Families and the Community (p. 59)

Accomplished Adolescence and Young Adulthood/Science teachers proactively work with families and communities to serve the best interests of each student.

The pages that follow provide elaborations of each standard that discuss the knowledge, skills, dispositions, and habits of mind that describe accomplished teaching in the field.

Preparing the Way for Productive Student Learning

This first section of *Adolescence and Young Adulthood/Science Standards* describes the background knowledge—about students, science itself, and science teaching—that accomplished teachers bring with them to the classroom. As the elaborations of these three standards make clear, such a description is necessarily incomplete because each of these aspects of accomplished practice is also continually evolving and being reshaped by the ongoing circumstances in the classroom. This section of the standards prepares the way for productive student learning; the sensibilities underlying it are cultivated and deepened throughout a teaching career.

Standard I: Understanding Students

Accomplished Adolescence and Young Adulthood/Science teachers know how students learn, know their students as individuals, and determine students' understandings of science as well as their individual learning backgrounds.

Accomplished science teachers believe that all students can learn science and that scientific literacy is not only essential for their future well-being but also well within each student's capacity to attain. These teachers³ are passionate about science and relish their interaction with the young people with whom they share this interest, frequently communicating in word and deed their high expectations for each student's success.

Accomplished teachers are aware of the differing ways and rates in which students process information on their path to understanding science. They know how to effectively use current and emerging theories of cognition and learning, such as multiple intelligences and schema theory, to implement lessons that enable students to make meaningful and demonstrable gains in the learning of science. (See Standard III—*Understanding Science Teaching* and Standard IX—*Assessing for Results*.) Accomplished teachers know that learning builds on prior mental constructs and experiences. Teachers design tasks and introduce issues that align with students' existing knowledge in order to move them forward.

They inquire about students' prior experiences in science and their beliefs and attitudes about science. They use this knowledge and their knowledge of science and science teaching to frame their practice equitably to meet the needs of each student.

Teachers take measures to ensure that they know their students as individuals inside and outside the classroom. They know, for example, who speaks English as a new language, who has difficulty understanding academic English, who has a special learning need or a chronic medical condition, who takes part in school activities, and who works after school. Accomplished teachers also recognize the broad array of students' recreational choices and interests that shape teenage culture. They understand how television, movies, music, and sports influence teenage priorities, and they show a level of care and concern by becoming familiar with popular trends.

Understanding each student entails gaining a sense of each student's science literacy. Accomplished teachers know which students have a special aptitude for or interest in science. They understand each student's

3. All references to teachers in this document, whether stated explicitly or not, refer to accomplished Adolescence and Young Adulthood/Science teachers.



confidence in using the inquiry processes; fluency in the language of science, mathematics, and technology; and background knowledge that is brought to class concerning natural phenomena, the history of science, the relationship between science and technology, and the impact of science on society. They design their lessons by considering how students with diverse abilities, interests, habits of mind, experiences, linguistic heritages, socioeconomic status, ethnicities, religious traditions, sexual orientations, body images, geographic references, and family backgrounds and configurations come to understand science. (See Standard VI—*Promoting Diversity, Equity, and Fairness.*)

Accomplished teachers' appreciation of each student as an individual science learner is rooted in their extensive experience working with students and a broader knowledge of the learning characteristics and developmental tendencies of the adolescents and young adults they teach. For example, accomplished teachers know the misconceptions that students of a given age typically bring to school and to the specific content areas; teachers use this information to frame activities that lead students to question and reconsider their thinking. (See Standard III—*Understanding Science Teaching.*) They know, for example, that many students naively believe that light travels from the eye to the object; that the Northern Hemisphere is hotter in the summer than the winter because the sun is closer to Earth at that time of year; or that condensation comes from cold water leaking through glass. Teachers anticipate the patterns of error that accompany a given topic and take steps to dispel them through appropriate activities and discussion. At the same time, accomplished teachers are sensitive to how the cultural, religious, and personal backgrounds of their students shape students' view of scientific discovery, such as the use of drugs for medicinal purposes, or the use of energy and new

power forms in ways that may raise environmental concerns.

To gauge their students' strengths, needs, and interests, accomplished teachers not only make learning about their students a priority, they also are resourceful in doing so. They constantly read their students' responses to what happens in class to determine whether learning is progressing satisfactorily. In addition, they use a variety of assessment practices to inform their instructional decisions and to assist students' understandings. In their classrooms, assessment does not occur in isolation at the end of a teaching sequence but is an ongoing aspect of teaching practice. (See Standard IX—*Assessing for Results.*) Even after they have established a baseline knowledge of their students, teachers continue to expand their understanding of their students throughout the year by keen observation and listening.

The degree of knowledge that any teacher can acquire about students may be partly a function of class size and teaching load, but accomplished teachers are resourceful and energetic in learning about each student. Teachers make themselves available and approachable both in their classes and outside the classroom on an informal basis.

In the course of their high school years, adolescent and young adult students begin to consider options for the future. Accomplished teachers recognize that many factors influence students' decisions, but they know that in all cases, students need a solid grounding in science to consider fully the academic and career paths open to them. This has always been true, and it is more so today as the reach of science and technology extends to the growing percentage of careers that hold the most promise. For many students, choosing whether to invest their time in the study of science is as much a decision about personal identity as a reasoned, intellectual one. Accomplished teachers make students and their families more aware of both the short- and long-term benefits of science education,

including the career paths that science education can open up to them.

Accomplished Adolescence and Young Adulthood/Science teachers know how to make valuable science experiences available to all their students, whatever their post-secondary choices. Teachers understand that students with differing social and cultural backgrounds will often have different views on the relevance of science experiences and on ways to apply science to their lives. Both these facts lead accomplished teachers to pose meaningful questions and to craft problems that students will likely find worthwhile. At the same time, they give their students opportunities to actively design some of their own paths for learning. Such teachers know that students often relish the

chance to have a voice in selecting what scientific questions to explore and determining how they might be investigated. An accomplished science teacher knows that students need opportunities to explore invigorating questions, such as “Why does the sun appear larger in winter in the Northern Hemisphere?” These teachers use all their accumulated knowledge of students, of science, and of teaching science to interpret their students’ behavior and to design meaningful experiences that ensure that all students are able to explore the wonders of the natural and engineered worlds.



Reflections on Standard I:

Standard II: Understanding Science

Accomplished Adolescence and Young Adulthood/Science teachers have a broad and current knowledge of science and science education, along with in-depth knowledge of one of the subfields of science, which they use to set important and appropriate learning goals.

The ability to steer a purposeful, yet flexible and responsive, learning course through the school day and year presumes, among other things, that the teacher has command of the subject matter. Indeed, all the central acts of teaching science—choosing or designing worthwhile activities, guiding discussion, responding appropriately to student questions and initiatives, negotiating instructional goals—require it. But what, exactly, is the knowledge base that an accomplished science teacher must command, given the extraordinary vastness of the domain of science?

Accomplished Adolescence and Young Adulthood/Science teachers must be scientifically literate. Such teachers must be well versed in (1) the nature of science and science as inquiry, including habits of mind, attitudes, and dispositions; (2) the fundamental concepts, laws, and theories that demarcate the content knowledge in the earth and space sciences, life sciences, and physical sciences; and (3) the historical, social, cultural, and technological contexts out of which the science enterprise has developed and in which it functions today. Accomplished science teachers supplement their broad knowledge of science with a deep and specialized knowledge of earth and space science, life science, or physical science (chemistry and/or physics).⁴

Nature of Science and Science as Inquiry

Accomplished science teachers have a thorough comprehension of science as an approach to building a consistent, testable set of understandings about how the world works. They recognize which kinds of questions fall within the purview of science and which do not. They are aware and respectful of other ways of interpreting the world; however, they also recognize and understand that the processes of science have a rigor and a predictive power all their own to which all students deserve access. Science teachers know what qualifies as authentic scientific investigation. They have a clear sense of the various strategies that scientists might use to frame an inquiry and open questions for further exploration; of the central importance of basing conclusions on empirical evidence; of the values and habits of mind that characterize the scientific endeavor; and of the importance of clearly communicating results to the scientific community.

Having a clear understanding of the nature of science is essential for the teaching of adolescents and young adults. It is essential because, as Henri Poincaré so eloquently noted, science may be made up of facts, “but a collection of facts is no more a science than a heap of stones is a house.”⁵ Teachers know that making connections among facts helps students define systems of operation in the natural and designed world, such as body systems, rock formations, and hydrostatic and

4. This standard provides an overview of the science teacher's knowledge base and draws directly from the consensus in the science community represented by the National Research Council's *National Science Education Standards* (Washington, D.C.: National Academy Press, 1995) and the documents that preceded it, including the American Association for the Advancement of Science's *Science for All Americans* (New York: Oxford University Press, 1990) and *Benchmarks for Science Literacy* (New York: Oxford University Press, 1993) and the National Science Teachers Association's *Scope, Sequence, and Coordination of Secondary School Science: The Content Core* (Washington, D.C.: National Science Teachers Association, 1993).

5. Poincaré, Jules Henri. *Science and Hypotheses* (Paris: Flammarion, 1902).



electrical systems. Students must experience the vitality of science in school before they can see science as a creative way of looking at the world and as a way of answering questions that matter to them. Only teachers who understand how science works, who hold a broad understanding of the role of skepticism in science, who know how ideas change as new evidence becomes available, who appreciate the fluidity of science, and who embody the openness to fresh ideas characteristic of first-rate scientists can model its processes, values, and habits of mind in the classroom. It is this clear understanding of the nature of science that enables teachers to foster a student understanding of science that distinguishes between science, such as evolution and astronomy, and non-science, such as creationism and astrology. And only teachers who understand the inquiry process can involve their students in doing their own consistent, strategic, logical, and legitimately scientific investigations.

The transformation of a classroom of students from a group of passive individuals into a community of actively engaged learners is the hallmark of excellent science instruction. (See Standard V—*Sustaining a Learning Environment*.) For accomplished science teachers, a starting point for establishing such a productive learning climate is a deeply structured knowledge of the nature of science and the inquiry process.

The Fundamental Concepts and Content Knowledge

Accomplished science teachers possess a broad grasp of the fundamental concepts, laws, principles, theories, facts, and ideas that constitute the body of scientific knowledge. Science is a collaborative social enterprise that builds on the achievements of previous generations. Accomplished teachers

understand the major conceptual paradigms that researchers have developed over the years in the core science disciplines and use this knowledge to inform their practice. They understand the common misconceptions that their students may hold, including the research identifying these incorrect ideas. They also follow trends in the field to keep their knowledge and pedagogy current.

The content knowledge of accomplished teachers is centered around the unifying concepts and processes of science. Accomplished teachers in all subfields of science thoroughly know about systems, order, and organization; evidence, models, and explanation; constancy, change, and measurement; evolution and equilibrium; form and function; and cycles, and they apply their knowledge in their teaching practice.⁶ The understandings that characterize the knowledge base of the accomplished science teacher are notable for their integrated quality.

Accomplished science teachers should have strong content knowledge—that is, college-level proficiency—in earth and space science, life science, and physical science. They should also have advanced proficiency in at least one area and some research experience that includes designing their own laboratory investigations and exploring research of other scientists. Although all accomplished science teachers have a foundation of scientific knowledge that cuts across the disciplines, science teachers of adolescents and young adults tend to specialize in a single discipline while recognizing the need for integrated presentations of science. Such teachers demonstrate a depth of knowledge about earth and space science, biology, chemistry, or physics that permits them to hold their students' interest and present an intellectually challenging curriculum. This in-depth level of knowledge means that teachers have engaged in focused study of these sciences beyond the introductory college level. Additionally, accomplished teachers

6. These unifying concepts and processes are referenced in the National Research Council's *National Science Education Standards* (Washington, D.C.: National Academy Press, 1995).

recognize the importance of mathematics in science teaching and are proficient in its application, including the use of algebra, geometry, statistics and probability, and discrete mathematics in modeling and solving science problems. Knowledge of calculus is important to understanding many emerging and ongoing theories across all science disciplines and is therefore recommended.

Earth and Space Sciences

Accomplished teachers understand the origin, composition, and structure of the universe. They understand that Earth and celestial phenomena can be described by principles of relative motion and perspective, including the uniformity of materials and forces found everywhere in the universe, and the motions of the Earth and the materials and systems that compose it. They also know that many of the phenomena observed on Earth involve interactions among components of air, water, and land, driven by the transfer of energy. Accomplished teachers understand that matter is composed of particles whose properties determine the observable characteristics of matter and its reactivity. They understand the cycling processes that shape the Earth's surface and the relationship of these processes to the living environment, for example, to the Earth's atmosphere and oceans.

Life Sciences

Accomplished teachers understand the diversity and unity that characterize life at the organismic and molecular levels; the genetic basis for the transfer of biological characteristics from one generation to the next and the molecular basis of genetic engineering; the structure and function of cells and the implications of their dysfunction; and the life cycle, particularly in reference to the human organism. They understand the dependence of all organisms on one another and on their

environment; the cycling of matter and the flow of energy (under the laws of thermodynamics) through the living environment and the maintenance of a constant internal environment; the behavior of organisms; and the basic concepts of evolution of species and the consequences of the loss of species.

Physical Sciences

Accomplished teachers understand the similarities and differences of basic properties of matter and the principles governing their interactions; the forms that energy takes, its transformations from one form to another, and its relationship to matter; motion and the principles that explain it; the nature of atoms and molecules and the ways atoms and molecules can be transformed into different arrangements of matter; and the forces that exist between and within objects and atoms. They know how to use this knowledge of energy to interpret, explain, predict, and influence change in our natural world.

The science topics within earth and space science, life science, and physical science reflect the central goals of well-regarded K–12 school science curricula. The correspondence between the science curriculum and the breadth of science knowledge expected of an accomplished teacher is deliberate. Science teachers at all levels know the fundamental facts and concepts of all areas of science that students have been charged with learning, in addition to their in-depth knowledge of one area.

Several examples will help to elucidate the in-depth knowledge of accomplished teachers in a single discipline of science. First, consider a brief illustration of the difference between the knowledge base of all accomplished science teachers and that of the accomplished teacher who specializes in earth science. All teachers would know that energy enters the Earth system primarily as solar energy, that sources of internal energy



are gravitational energy and the decay of matter, and that vertical ocean currents impact organisms. An accomplished teacher specializing in earth science would not only know that energy enters the Earth system primarily as solar radiation, but also would understand the connection of this energy to reflection, absorption, and photosynthesis; would not only know that convection within the atmosphere and oceans produces winds, but also could explain how differential heating results in circulation patterns in the atmosphere and oceans that globally distribute the heat; and would not only know that there are ocean currents, but also would be able to explain the properties of ocean water to describe the layered structure of the oceans, the generation of horizontal and vertical ocean currents, and the geographic distribution of marine organisms. Furthermore, a specialist in earth science would understand and convey to students how convection currents within the asthenosphere drive the movement of plates and can relate the movement of convection currents to changes in densities of fluids caused by the transfer of heat energy.

Second, consider an illustration of the difference between the knowledge base of all accomplished science teachers and that of the accomplished teacher specializing in biology. All science teachers would know that cells are the basic unit of living things and why this fact is important, that cells carry out the important functions of life: growth, reproduction, excretion, digestion, movement, synthesis, and response; how these functions occur; and how they vary across different organisms. An accomplished teacher specializing in biology or physiology would not only know that the cell membrane controls which molecules can enter and leave the cell, but also could explain the mechanics of the membrane's selective permeability in terms of the fluid-mosaic model; would not only know that the cell nucleus contains the coded instructions

for building specialized proteins, but also could describe how double helix DNA molecules initiate this function in conjunction with various RNA molecules; and would not only know that there are structures inside the cell that perform functions essential for the cell's survival, but also would be able to identify specific cytoplasmic organelles, such as mitochondria/chloroplasts and explain their part in cell respiration/photosynthesis.

Third, consider the difference between the knowledge base of all accomplished science teachers and that of the accomplished teacher specializing in chemistry. All science teachers would know that all matter is composed of atoms; that atoms are made up of electrons, protons, and neutrons, and that the atoms of an element all contain the same number of protons in the nucleus; that there are 90 naturally occurring elements; and that very few elements are found in pure form because most elements are found in compounds. An accomplished teacher specializing in chemistry would not only know that there are naturally occurring elements, but also could provide detail about cosmology and how the naturally occurring elements are said to be formed, as well as detailed explanations on the isotopes of elements, the energetics of the decay of isotopes and its various bi-products, and the determination of atomic and relative mass. The accomplished teacher specializing in chemistry would not only know that electrons are found in the region about the nucleus, but also could describe the electron energy levels and explain how electronic structure determines the nature and type of bonds between atoms or groups of atoms by using basic calculus and quantum theory; and would not only know that there are electronic structures that influence the way atoms combine, but also would be able to explain characteristics and properties of various compounds and molecules formed by elements and explain the importance of the form and function of the periodic table.

Fourth, consider the difference between the knowledge base of all accomplished science teachers and that of the accomplished teacher specializing in physics. All science teachers would know how to make and use position-time and velocity-time graphs to describe the position, velocity, and acceleration of a moving object; identify forces on a static and moving body in two dimensions; and explain static and moving charges in terms of an electron model. An accomplished teacher specializing in physics would not only know how to use position-time and velocity-time graphs, but also would know how to use vector analysis and basic calculus to make predictions about a moving object; would not only know how to identify forces on static and moving bodies, but also could predict and describe those forces in terms of a Newtonian force model; would not only know how to explain static and moving charges in terms of an electron model, but also would be able to explain the relationships between electricity and magnetism using Maxwell's equations.

This significantly more comprehensive, sophisticated, and embellished knowledge of a particular discipline joins with a corresponding command of discipline-specific pedagogy that permits the accomplished Adolescence and Young Adulthood/Science teacher to practice at a high level. Such teachers possess a repertoire of instructional materials, experiments, demonstrations, analogies, and metaphors, along with an understanding of common misconceptions, puzzlements, and conceptual difficulties that are likely to challenge students. The wisdom of their practice allows them to interpret student actions accurately and helps them judge when and where to turn to various aspects of their teaching repertoire. Together these two vital aspects of professional knowledge elevate teaching practice. Without regard to whether a teacher claims a particular specialty or has an all-science licensure, the answer to the depth question

must always be couched in terms of the functional usefulness of the teacher's knowledge as applied in classroom practice. In any area of science, it is the overall depth of the science teacher's understanding of a topic, not fact recall, that is at a premium.

Historical, Social, Cultural, and Technological Contexts

Accomplished science teachers understand science as an expression of the deep human impulse to explore and learn ever more about the natural world. They are acquainted with the history of science, including the key episodes in the development of the scientific world picture, and with the contributions of many cultures in both ancient and modern times. In addition to recognizing the difference between scientific and non-scientific questions, teachers understand what science and technology can or cannot reasonably contribute to society. They comprehend the ethical questions that science presents and bring such habits of mind as honesty, objectivity, and social responsibility to their teaching.

Accomplished teachers can connect science to personal and social perspectives that are meaningful to students. They connect the unifying concepts and science content areas to personal and community health; population growth; natural resources; environmental quality; natural and human induced hazards; and science and technology in local, national, and global challenges. To illustrate these connections, teachers know classic examples. For instance, teachers know about the cholera epidemic in nineteenth-century England whereby physician and epidemiologist John Snow was able to prove that the disease spread through water, and they understand how this discovery eventually led to the development of the

vacuum pump to transport water safely. Teachers also know current examples that can help students make connections between what students learn in class and what happens in the news.

Accomplished science teachers are aware of the interdependent and reciprocal relationships that have developed over the centuries among technology, mathematics, and science knowledge. They know how to use mathematics as a language to articulate scientific relationships and thereby to extrapolate or predict relationships from one context to another. They understand that science and technology are pursued for different

purposes. While science as inquiry seeks to understand the natural world, technology is driven by the desire to meet human needs and solve human problems. Accomplished teachers understand that science and technology have exercised enormous influence over the course of human affairs and are aware of many instances of technology-driven change as well as the unforeseen consequences and social, political, and ethical dilemmas that frequently attend this change. (See Standard VIII—*Making Connections in Science*.)



Reflections on Standard II:



Adolescence and Young Adulthood/Science Standards

Standard III: Understanding Science Teaching

Accomplished Adolescence and Young Adulthood/Science teachers employ a deliberately sequenced variety of research-driven instructional strategies and select, adapt, and create instructional resources to support active student exploration and understanding of science.

Accomplished science teachers understand the social nature of scientific learning and how peer investigators critique and build on one another's cumulative achievements. Accomplished teachers know content, and they also know what content is difficult to teach and what is difficult to learn. They know that all students must have access to the vast accumulation of scientific knowledge, its history and lore, its relations to technology, and its impacts on society if they are to become scientifically literate in the fullest sense of the term. Teachers constantly balance two mutually complementary responsibilities—that of encouraging students' explorations in science and that of guiding them toward an expanded understanding of scientific knowledge. Teachers use a wide variety of instructional resources, such as laboratory equipment and materials, technological tools, print resources, and resources from the local environment, as they create memorable learning experiences for their students.

Planning and Sequencing of Science Curriculum and Instruction

Accomplished science teachers recognize that science is best taught within an articulated K–12 curricular structure developed around the major conceptual ideas in

science, as identified by local, state, and national standards. Such an organizing template for curriculum and instruction reduces unnecessary repetition of material from one year to the next and, instead, sequences K–12 science curriculum to ensure a deepening of student understandings of particular concepts, appropriate introduction of new concepts, and a richer appreciation for how the various sciences reinforce one another. Accomplished science teachers in districts without such an articulated K–12 structure work to establish one.

In planning and sequencing curriculum and instruction, accomplished science teachers understand the need to give students access to the fundamental facts, concepts, laws, and theories of science without burying them under an avalanche of esoteric detail, and they thoughtfully organize curriculum and make pedagogical decisions with this need in mind. The problem with scientific facts is the incredible rate at which they are discovered and propagated. Just keeping track of the names of the various subspecialties in modern science is a daunting task; all the more daunting would be knowing the details of each. In making curricular choices, accomplished science teachers focus especially on fostering in their students deep understandings of topics. For example, they organize scientific information in the context of larger unifying concepts (such as evolution, the relationship of structure and function, cause and effect, energy flow) that cut



across the various science disciplines and suggest the larger patterns found in the natural world.

Goal setting in the accomplished science teacher's classroom is an interactive process. In most cases, instructional goals are initially defined broadly at the local, state, and national levels. With these standards and guidelines as a foundation, teachers establish long-range learning goals that are rigorous, worthwhile, and sensible to students. Accomplished teachers then organize, structure, and sequence learning activities that reflect these goals, and they plan assessments that will measure progress toward these goals. The actual executing of the activities is tailored to student needs and often includes a strong element of student initiative and direction.

Accomplished teachers connect what they are teaching today with what they taught the day before and lay the groundwork for what they will teach next week; that is, their teaching is most effective when it reflects a well-planned continuum. They understand the significance of when topics are introduced, how they are organized, and what level of cognitive sophistication they require. For example, an accomplished teacher might teach an ecology unit at the beginning of the school year to take advantage of the changing seasons and to give students time to mature and acquire the higher-level skills that they will need to deal with more abstract ideas, such as DNA.

Sequencing within a particular lesson is also important. For example, accomplished teachers make appropriate use of explicit introductory or summative teaching on essential science topics as part of a continuum of strategies. They recognize the importance of debriefing on activities for appropriate closure. The debriefings pull together the pieces of a hands-on experience to find out if students have met the intended learning goals, and if they have developed misconceptions that should be addressed in subsequent lessons.

Accomplished science teachers base their professional judgments about science curriculum and instruction on data collected from multiple sources. Their familiarity with contemporary research in science and science education enables them to evaluate a wide variety of instructional strategies and tools and to weigh evidence from research when making judgments that affect instruction in their classroom. They also continually collect and analyze data about their students' and school's performance to inform decisions they make about curriculum and instruction. They interpret data from students in multiple ways, including disaggregating the data to analyze students' performances. (See Standard I—*Understanding Students* and Standard IX—*Assessing for Results*.) They may conduct their own research, including classroom-based research, to inform their planning and instruction and that of their colleagues in the school and the community at large. (See Standard X—*Reflecting on Teaching and Learning* and Standard XI—*Developing Collegiality and Leadership*.)

Implementation of Science Curriculum and Instruction

To introduce and deepen conceptual knowledge in science, accomplished teachers purposefully design and implement a wide variety of science activities. Through substantive laboratory experiments, field experiences, the use of physical models, simulations, and other activities, they involve students in actively conducting their own scientific investigations. Written assignments, such as laboratory reports, reflection notebooks, and research projects, promote student analysis of science concepts and advance student literacy skills. Accomplished teachers inform students through a variety of science-rich readings (both assigned to a

whole class and chosen independently by each student) that extend, contextualize, and enrich their hands-on science experiences. Accomplished teachers carry out demonstrations that dramatize underlying scientific principles and provide opportunities for group analyses. They introduce students to excellent and scientifically pertinent multimedia resources. They lead discussions and set up opportunities for small-group talk to help students digest new ideas and to make public useful strategies for promoting independent science thinking and effective science communication skills. Accomplished teachers develop a systematic approach to the teaching of concepts through research-based instructional strategies.

Accomplished teachers can effectively balance helping students become confident in the practice of science and inculcating knowledge in them about the key organizing paradigms, terminology, and qualitative and quantitative concepts in the main scientific domains. These two aspects of the same unifying goal—scientific literacy—inform the daily instructional rhythm of their classrooms. For example, in teaching a unit about chemical reactions to adolescents and young adults, a teacher might arrange for students to participate in a variety of experiences in the laboratories, such as timing reactions that have a visible end point and comparing the rate of reaction at different temperatures, at different concentrations of reactants, and in the presence or absence of catalysts. The results of these experiments, relating reaction rate to the frequency and energy of molecular collisions, might then be translated visually in terms of a molecular model showing the structural rearrangements that occur during a simple chemical reaction. A look at some common industrial chemical practices (from the refining of petroleum to the functioning of the catalytic converter in the family car) might bring home to students the many practical applications of knowledge about factors affecting reaction rates. Accomplished

teachers are deliberate in helping students become increasingly independent in linking science concepts to real-world experiences.

To assist students in understanding difficult content, accomplished teachers translate complex ideas into terms more available to their students. They know the best analogies and demonstrations to use in presenting difficult science concepts and constantly expand their repertoire of verbal and visual aids. When using an analogy (for example, the work of mitochondria in a cell is much like that of a power generator in a building), teachers make sure that students understand not only where the valid similarities exist (both provide usable energy to run activities within a cell or a building), but also where the analogy breaks down (generally, a building has a power generator controlled by humans whereas mitochondrial activities are controlled by a series of biochemical reactions).

Overall, accomplished teachers operate with a sense of purpose in the classroom and know how to adjust their practice, as appropriate, to student performance and feedback. They make midcourse corrections when an activity falters and quickly improvise when an unanticipated learning opportunity presents itself. They are willing to allow student learning to steer the direction of a lesson, but do so in ways that uphold the overarching conceptual framework and that promote accurate understandings. As a result, students have a stake in what happens in science class, even though their every suggestion may not be pursued. Teachers know their field and their students, including the fact adolescents and young adults work most productively in science when they have interest and ownership in the questions being investigated. Teachers act as facilitators of students' intellectual explorations and initiatives and help guide them toward scientifically valid mental constructs about how the natural world works.



Instructional Resources

No classroom is an island. A variety of instructional resources—from laboratory materials and the tools of technology to print texts and resources from the local environment—can help students make the connections among the study of school science, their lives, and the world of science. Accomplished teachers select, adapt, create, and use an array of diverse instructional resources to engage students in meaningful learning. They continually mine the wealth of materials available for lesson plans, laboratories, and activities found on Web sites, in professional publications, at conferences and workshops, and from networking with other science teachers, and they add these to their repertoire. They tap into these instructional resources by choosing wisely among selections and by making optimum use of those that have been secured. They also recognize the rapid evolution of resources in science and keep abreast of new materials, tools, and techniques that they can incorporate into their classroom.

Laboratory Resources and Technology Tools

Laboratory equipment and technology, used properly, extends and enhances the learning experience for students. Anyone who has seen a young student's face light up with understanding after studying a drop of pond water under a microscope knows the truth of this statement. Traditional types of equipment, such as test tubes, balances, and metersticks, have long had a prominent role in effective science programs. In addition, accomplished teachers have in their instructional repertoire knowledge of modern laboratory tools and techniques that sufficiently prepare students for a wide range of post-secondary choices related to science. Instructional technology devices, such as graphing calculators, desktop

and handheld computers, probes, and Web-based resources, are becoming increasingly available and useful, as more sophisticated interactive education software is developed for them. Accomplished science teachers know how to make full use of this array of tools, as well as other emerging technologies, in ways that contribute to students' active science explorations and accurate understandings. Teachers who do not have access to advanced equipment use all available technology and tools, no matter how basic, and advocate for improved resources. They also teach about advanced technology tools, to prepare their students for access to these resources in the future.

The tools of electronic technology can assist in collecting, analyzing, and reporting laboratory data; serve as reference stations; and extend the range of experiences available to the student. Experiments too dangerous, too costly, or only available at a distance can be brought into the classroom for collaborative data analysis through the Internet. For example, students from different areas of the country can exchange information about the pH of local rainfall and gain insights into national and global weather patterns, air pollution, and energy pathways, while enriching their ability to make scientific connections using original data. Video and digital cameras allow students and teachers to collect data on many phenomena—for instance, documenting the phases of the moon, analyzing color, or quantifying complex motions, as well as bringing their own science-related projects and experiences into the classroom for discussion. Accomplished teachers also understand the importance of communicating information in varied media that best convey the intended message or analysis, and they design instruction so that students use such tools as multimedia presentations. Teachers have students take advantage of these technology tools to aid the students' thinking; they know that scientific knowledge results from making sense of information, not from raw data itself.

Accomplished teachers also take otherwise passive uses of technology, such as the presentation of a video clip, and make them active and student-centered through previewing activities, discussion during viewing, and follow-up activities. For example, teachers might have students use an action sequence of a film clip to calculate the velocity and acceleration of moving bodies.

Teachers promote independent student use of resources for learning as much as possible. They provide hands-on experiences with mechanical, electrical, and optical tools. They help students develop a positive attitude toward the use of tools and instruments as an extension of the five senses. Accomplished teachers are well aware of the safety issues relevant to student use of some equipment and materials. They understand how to adapt tools and procedures, so students can participate fully in scientific investigations without compromising either safety or academic rigor. (See Standard V—*Sustaining a Learning Environment*.)

Print Resources

Accomplished teachers know that readings can serve as important auxiliaries to their students' growth in science literacy. They use written texts to support carefully planned curricular goals, instructional strategies, and ongoing assessments, not as a curricular formula to be blindly followed or as a substitute for the exercise of professional judgment. They have clear criteria for evaluating the quality of textual materials, including such factors as the accuracy and depth with which a limited number of topics are treated; the thought-provoking and engaging quality of the prose; and the recognition of the contributions of many cultures and diverse individuals to the development of science and technology. Teachers direct students to sources of related information—the library media center, science periodicals, monographs, Web sites,

or databases—so that the textbook is never seen as the sole source of scientific knowledge. They know and can articulate their reasons for having students use a particular text. They teach students strategies that enable them to comprehend expository texts and graphics successfully. They also help students evaluate the credibility of sources and the validity of information.

Local Environment as Resource

The local environment provides another rich resource for science teachers to use to expand student science learning. For example, teachers might take students to local nature preserves, wetlands, parks, deserts, zoos, or rivers to do research. Teachers might also ask students to bring in rock and soil samples from their own neighborhoods to study at school or to map the school grounds for flora and fauna. Using the local environment not only enriches science understanding but also helps students make connections among the science disciplines. (See Standard IV—*Engaging the Science Learner* and Standard XII—*Connecting with Families and the Community*.)



Establishing a Favorable Context for Student Learning

This second section pertains to those aspects of professional practice—motivating effort, shaping the classroom culture, and engaging and holding high expectations for all students—that enable Accomplished Adolescence and Young Adulthood/Science teachers to create a positive learning environment.

Standard IV: Engaging the Science Learner

Accomplished Adolescence and Young Adulthood/Science teachers spark student interest in science and promote active and sustained learning, so all students achieve meaningful and demonstrable growth toward learning goals.

Perhaps the clearest indication of accomplished teaching in any discipline can be found in the response of students. The students of accomplished science teachers are constructively engaged in building deep and profound knowledge of the natural and engineered worlds. Students participate creatively in solving problems, offer ideas and listen attentively to the hypotheses of others, and generally display their involvement in and enjoyment of the process of discovery. Accomplished science teachers move their students toward meaningful and demonstrable learning gains in science by enlisting their students' concerted effort and engaging them actively in learning.

Accomplished teachers are passionate about science; they exhibit a contagious enthusiasm in their teaching of the subject, its technological applications, and the natural world around them. This excitement need not be expressed ostentatiously; what is key is that students see that the pursuit of science is a source of intellectual satisfaction and intrigue for their teachers. Teachers are lifelong learners; for them, studying the natural world is like following the plot twists of an exciting thriller. They have a solid knowledge base in science, yet they are codiscoverers alongside their students, demonstrating that false starts, blind leads, mistakes, and

anomalous results are part of the inquiry process.

Whenever possible, teachers choose activities and topics that relate to their students' interests, experiences, and cultures and that support the curriculum they teach. They also draw on current events regarding science. Science is presented as a way of knowing concepts that explain how and why things happen the way they do, in a way that builds on and enlivens the concepts. Accomplished teachers know that focusing on the technological applications of a scientific principle can be a particularly effective way of grounding a discussion in the students' reality.

Accomplished teachers do not simply present a topic; they introduce it in a captivating way. For example, they may use the novelty of a natural phenomenon (a fish that can change its gender) or the discrepancy between what students expect to happen and what actually occurs (blowing air over the top of a piece of paper raises it) to pique their students' interest. In general, teachers introduce knowledge about science in the form of questions to be explored rather than answers to be learned. As teachers engage students actively in learning, they closely monitor students' progress and make adjustments in their instructional approaches as needed. (See Standard IX—*Assessing for Results*.)



Adolescence and Young Adulthood/Science Standards

Accomplished teachers also extend science learning through student involvement beyond the classroom. For example, accomplished teachers may integrate science learning with promotion of civic responsibility by making students aware of nearby service organizations that have a scientific component. They may also search out meaningful projects that are feasible for students to undertake, ranging from engaging students in science fairs and other science competitions to developing campaigns to encourage healthy nutritional habits or community recycling, or designing

water-conserving gardens in drought-susceptible communities. (See Standard III—*Understanding Science Teaching* and Standard XII—*Connecting with Families and the Community*.)

Through innovative and effective methods, accomplished science teachers are able to capture students' interest and energy and channel them toward meaningful learning goals.



Reflections on Standard IV:

Standard V: Sustaining a Learning Environment

Accomplished Adolescence and Young Adulthood/Science teachers create safe, supportive, and stimulating learning environments that foster high expectations for each student's successful science learning and in which students experience and incorporate the values inherent in the practice of science.

Influencing the quality of human associations—how students interact with one another and with the teacher—is a significant aspect of creating a productive learning environment that favors both the academic and the personal growth of students. Teachers know that students from diverse backgrounds can learn from one another in the context of a positive class environment. Accomplished science teachers deliberately foster settings in which students play active roles as science investigators in a mutually supportive learning community.

Such teachers know that scientific work is best carried out in a cooperative, internally regulated, social context. Scientists cooperate on an international scale, subjecting one another's findings to validation by a community of peers. Consequently, individual scientists have a strong incentive to be as accurate, objective, honest, open to new explanations, and skeptical of their own conclusions as possible.

Like adults, students need a healthy, stimulating, and supportive work environment, one that welcomes the open expression of ideas and encourages the search for greater understanding and knowledge. Nonetheless, students sometimes find themselves in settings where abusive language, put-downs, sexual harassment, and bigotry are accepted and where prejudice and disrespect exist. From the outset of the school year, accomplished teachers actively combat such pernicious behavior. They foster a sense of community by encouraging student interactions that show concern for others and by

dealing constructively with socially inappropriate behavior. They create a community that ensures students' physical safety and is secure socially and intellectually as well. (See Standard VI—*Promoting Diversity, Equity, and Fairness.*) When using material that may make some students uncomfortable, accomplished teachers set such issues in appropriate contexts. They accommodate their students' sensibilities but do not eliminate important subjects for students. Without fail, teachers work to create instructional settings that promote learning for all students.

Central to creating such a learning environment is the personal example that teachers set with their own demeanor in the classroom and beyond. Accomplished science teachers are friendly and curious, unabashedly enthusiastic about their interest in science, and receptive to each student's contributions to the learning process. They are good listeners who are open to new ideas. They have a healthy sense of humor and a genuinely caring, respectful attitude toward students. Modeling supportive behavior and welcoming all students is second nature to accomplished teachers. They know their personal strengths and abilities in working with students, and they develop them to their maximum capabilities. They also work hard at extending themselves to students, often beyond the school day or at community events, recognizing that positive contact with students outside the classroom may well affect students' disposition toward the teacher, the subject, and the class itself.



Teachers also create a productive learning environment as a result of their organizational decisions. They are efficient classroom managers who know the importance of using scarce resources—including instructional time—well. They establish orderly and workable learning routines that maximize student time on task. Students know what is expected of them and are confident and willing to participate because they perceive that their explorations in science are serving their own purposes. Teachers invite students to be a part of the learning community by assigning open-ended tasks that require students to pay attention to the dynamics of their interactions with others.

Safety in the use of laboratory equipment is a paramount concern of science teachers. They instruct their students in the use of safety equipment, such as eye-protection devices, and enforce standard practices. They make students aware of their responsibility to follow proper laboratory procedures and, in general, ensure that safety concerns are not used as a rationale for the elimination of activity-based science. They model safe practices and use only approved processes while preparing and cleaning their classrooms. They ensure that all storage practices, materials, equipment, and experiments meet all safety guidelines.

Teachers understand that classroom management is, to a great extent, a function of student engagement. When students are invested in what they are doing in school, the learning environment becomes self-governing in many respects. By organizing science classes around issues and activities that emerge from students' experiences, teachers create a dynamic that favors learning. They use these opportunities to introduce issues that appeal to students of diverse backgrounds. At the same time, they recognize that even the best of students can have a bad day. When problems arise, teachers handle them fairly and respectfully. They are skilled at de-escalating confrontations and minimizing

disruptions to the learning process. They involve students in setting behavioral expectations and boundaries.

Teachers have high expectations for the growth in science literacy of each student. They understand that science literacy has many dimensions; it requires a thorough understanding of the fundamental concepts and processes of science and incorporates ways of thinking, patterns of discourse, and precise vocabulary. Accomplished teachers have a vision for the success of their students in science that the students might not be capable of having for themselves. They know when to praise and when to push. They also communicate in both explicit and nonverbal terms that they expect an honest, committed effort from every student.

Teachers know that genuine achievement motivates students to continue striving to do their best. At the same time, they understand that the threshold of success may vary from student to student. To accommodate these differences, accomplished teachers provide several avenues for learning by, for example, choosing open-ended activities that allow each student multiple paths to approach the core ideas in the curriculum. They understand that mathematics presents a barrier to some students and devise appropriate alternative activities that both provide access to the science concept in question and help students develop the needed fluency in mathematics. They also understand how to design instruction that allows students with exceptional needs, students with literacy difficulties, and English language learners to participate fully in class and achieve science literacy.

Teachers help students learn about and internalize the values inherent in the practice of science by relying on those values to shape the ethos of the learning community. They help students experience the fact that science makes progress through establishing a new consensus based on the strength of evidence and logical reasoning, not on

Standard VI: Promoting Diversity, Equity, and Fairness

Accomplished Adolescence and Young Adulthood/Science teachers ensure that all students, including those from groups that have historically not been encouraged to enter the world of science and that experience ongoing barriers, succeed in the study of science and understand the importance and relevance of science.

Accomplished science teachers know that giving each student equal access to an empowering science education requires responding sensitively to human differences and finding and building on individual strengths. They help students see that the drive to understand the natural environment is a basic, common, human one that individuals from all ethnic groups and cultures have engaged in through recorded time. Accomplished science teachers recognize that women, people of color, members of low socioeconomic groups, and students with disabilities and special learning needs historically have been discouraged and excluded from the sciences, both in academia and in the world of work. They work to ensure that these groups receive encouragement and interventions that facilitate full participation in science.

Accomplished teachers create classrooms that enable all students to succeed in the study of challenging and significant science. As a fundamental presumption, they believe that every student can succeed in science. They expect each of their students to work hard; they publicly acknowledge students who give an honest effort and are persistent in their prompting of underachievers. In their classes, no student is allowed to disappear. They promote a deep and sophisticated understanding of science in all students.

Teachers build on the strengths of all students. They know that every student comes to school with a unique set of experiences,

personal history, and knowledge of the world. They honor the diversity of aspects of culture that students bring into the classroom. They use examples derived from students' cultures, communities, and home environments to demonstrate the relevance of science and technology in students' daily lives and to pay public tribute to student-demonstrated expertise. Teachers also recognize the importance of recruiting family and parental participation in supporting students' science explorations and take measures to follow through on that knowledge.⁷ They work to ensure that all students have adult role models by finding mentors who encourage and support the scientific growth of their students, especially those who lack a significant adult presence in their lives. (See Standard XII—*Connecting with Families and the Community*.)

Teachers are aware that science may feel like alien territory to certain students—not just intellectually, but socially, culturally, and emotionally. Accordingly, they make sure that these students frequently hear and receive the message that “people like me” have excelled in science and that, therefore, they can too without sacrificing their group identity. Teachers keep role models of successful scientists from diverse backgrounds and from both genders before their students. They know and appreciate the significance of scientific developments from other cultures and the contributions scientists from other cultures have made to the understanding of the natural world. Teachers incorporate these elements

7. The word *parent*, or its derivatives such as *parental*, is used in this document to refer to the people who are the primary caregivers and guardians of children.



into instruction to enhance student knowledge, skills, and attitudes.

In the classroom setting, teachers proactively involve students from underrepresented groups in taking the lead in science. For example, they may frequently organize their students in small groups and have them work together toward a common goal. This technique, when properly applied, can significantly enhance the learning experience and achievement of students from underrepresented groups. Teachers are careful to monitor the participation of students in groups, making sure that all have an equal opportunity to participate in key roles and adjusting group membership as needed. For example, they may sometimes pair girls with girls and boys with boys during laboratory study to make sure that gender does not determine participation in laboratory experiments and investigations. Teachers are also strong advocates for students who need special accommodations to participate fully in the laboratory setting.

Accomplished teachers are especially aware of the issue of gender equity in science. They identify and address subtle signals that indicate girls and boys are having different science experiences, and they immediately stop overt sexual harassment, prejudice, or stereotyping. They ensure that resources in the classroom are equitably distributed and that all students engage in hands-on participation. They are careful to call on both boys and girls equitably and to allow the same wait time for responses. Accomplished teachers actively combat any suggestion that girls cannot—or choose not to—do science. They encourage all their students to pursue all subdisciplines of science.

Accomplished teachers acknowledge their own biases and recognize that these biases can affect their teaching. Through reflective behavior, they make sure that fairness and respect for individuals permeates their instructional practice. They recognize that certain groups benefit from an increased

likelihood of success in the science classroom and create ways to level the playing field and close the achievement gap for all students. For example, teachers understand the privilege that is often inherent in the high socioeconomic background of students, such as access to high-quality curricula, facilities, and equipment, and plentiful information about and access to science careers. Accomplished teachers create ways to bring these benefits and opportunities to all students. They level the playing field for, and close the achievement gap among all groups of students, while raising the science achievement of all.

Teachers realize that language itself may limit students' participation in science class and that difficulties with language affect a wide range of students. These students include learners of English as a new language, native English speakers who come from low-literacy backgrounds, and students with exceptional needs. Teachers understand the different requirements for comprehending narrative text and the expository text of science textbooks. Accomplished teachers are aware that the sophisticated and precise language of science can be a challenge for speakers of nonstandard English, and teachers help students properly use the language of the discipline without watering down either language or content. In working with all students, teachers use a natural speech rate with clear enunciation, choose their words appropriately and carefully, and frequently restate important points. They provide helpful nonverbal cues to meaning by using sensory aids to illustrate key ideas. They carry out regular comprehension checks to confirm whether students are following the concept under investigation. They ask students to brainstorm and list what students already know, and then build on that foundation—offering multiple communication options for those whose command of English is limited—in introducing new topics. Thus, they create opportunities for

students to communicate their knowledge and understandings as a means of developing student usage of academic science discourse. Teachers ensure that students for whom English is a new language have full access to the science curriculum, and they honor students' native languages.

Two of the most important techniques for working with students for whom English is a new language mirror key aspects of accomplished practice for all students. First, accomplished teachers frame science learning in terms of the major concepts. Second, rather than merely reiterate rote concepts, they provide instruction mediated by direct experiences so students can construct deep understandings that replace or are reconciled with previous mental schema.

Accomplished teachers remove, or at least reduce, other roadblocks to their students' success in science as well. For example, they

know that many students lack the numeracy necessary to study sophisticated science topics. Accomplished science teachers find ways to support, supplement, and increase the mathematical capabilities of their students. They ensure that even students who struggle mathematically have access not only to science education but also to science success. Teachers also work with students who have less familiarity with technology to help them gain facility in using the ever-changing tools available for scientific research.

Accomplished science teachers are dedicated to the growth in science literacy of all students and are prepared to do whatever it takes to make that occur.



Reflections on Standard VI:

Advancing Student Learning

This third section of *Adolescence and Young Adulthood/Science Standards* focuses on the direct effect that accomplished science teaching has on student learning. The overall goal of science instruction has already been described as the fostering of science literacy in all students. Consistent with the Introduction and the description of a teacher's background knowledge of science in Standard II—*Understanding Science*, science literacy is presented in this section in terms of developing in students three main capacities: experience with the science inquiry process itself, including the attitudes and habits of mind that characterize scientific investigation and advance students' learning of key science concepts (Standard VII—*Fostering Science Inquiry*); an awareness of the human contexts of science, including the history of its co-evolution with technology and mathematics and the impact of science and technology on civilization (Standard VIII—*Making Connections in Science*); and science literacy demonstrated through techniques for assessing student progress (Standard IX—*Assessing for Results*).

Standard VII: Fostering Science Inquiry

Accomplished Adolescence and Young Adulthood/Science teachers engage students in active exploration to develop the mental operations and habits of mind that are essential to advancing strong content knowledge and scientific literacy.

Scientific information is growing exponentially. Even fleeting coverage of the ever-expanding amount of scientific information would be impossible in school science. Accomplished science teachers know that, as important as it is for students to acquire the fundamental understandings of science, they must also learn the strategies and procedures for approaching a problem scientifically. A basic goal of science instruction is to help students acquire the mental operations, habits of mind, and attitudes that characterize the process of scientific inquiry—that is, to teach students how scientists question, think, and reason. In the classrooms of accomplished science teachers, students engage in scientific inquiry by drawing upon prior science content knowledge as they deepen and expand their understanding of science.

Science teachers understand that the inquiry process is not a uniform series of

predetermined steps and that scientists vary widely in how they seek knowledge about natural phenomena. Nevertheless, certain patterns in the methods of successful scientists are evident, for example, in their capacity to recognize problems, ask relevant questions, formulate working hypotheses, observe phenomena, record and interpret data and graphs accurately, reach tentative conclusions consistent with data, and express themselves clearly about the significance of findings. In the classrooms of accomplished science teachers, the scientific process is not a linear series of steps but a cyclical process based on data collection and the continual refinement of questions. Students' acquisition of these mental capacities, and the habits of mind and attitudes that underlie them, are central to the science curriculum.

Accomplished science teachers use the entire spectrum of inquiry, from teacher-



guided inquiry through student-driven investigations. They ensure that hands-on activities occupy their students intellectually and set the stage for increasingly sophisticated classroom discourse. This focus on the interchange of ideas, whether through discussions or the sharing of written work, is key, for through such discourse and consensus, a classroom of individuals seeking knowledge transforms into a community of learners seeking common understanding. As individual students communicate their observations to their peers, they discover to what extent their perceptions are shared—and if not, why not. In the course of this multidirectional conversation, students refine, articulate, and elaborate on their own understandings of the natural world while developing an understanding of the rules of evidence and modes of argument that guide the inquiry process, as well as learning vocabulary characteristic of scientific discourse.

How is that ability in inquiry best facilitated? Teachers recognize that students profit from doing. To learn to view the world through a scientific lens, students must have abundant opportunities to practice the myriad of skills that such an ambitious goal entails. They must have frequent opportunities to take part in hands-on science activities that are followed by designated time to reflect on the significance of what they have done. For example, accomplished teachers promote long-term investigations and authentic student research in and beyond the classroom. They make full use of available scientific techniques and technology and capitalize on the laboratory resources they have available. They know that many times an idea or concept can be addressed by an activity using household materials, such as string, masking tape, or balloons, rather than an expensive piece of equipment. Accomplished teachers in technology-rich environments make full use of the resources available, such as data-acquisition hardware and software, imaging technologies, and tools of biotechnology.

They introduce their students to data available from outside sources and teach the critical-thinking skills necessary to evaluate such sources.

Accordingly, teachers organize their classrooms around frequent, open-ended investigations of natural phenomena in which students initiate the pursuit of knowledge. In choosing or designing activities, teachers keep a number of important criteria in mind to ensure that the activities are standards-based and lead to significant learning. They use science and science education research to help find activities that are age-appropriate to the developmental level of their students; likely to raise interesting, worthwhile questions; relevant to the lives of all their students; and flexible. (See Standard III—*Understanding Science Teaching*.) A good activity allows active participation and student control over manipulating variables, posing questions, and using technology and data analysis. Accomplished teachers also select activities that engage students in using and improving their research and communication skills, such as writing laboratory reports and preparing presentations with graphs and visual displays. As part of research projects and investigations, accomplished teachers teach students how to integrate laboratory data with research from a variety of printed and electronic resources in ways that effectively communicate the results of student investigations.

Teachers know that the processes of science are underpinned by such qualities as curiosity, openness to new ideas, skepticism, the demand for evidence, respect for reason, honesty, objectivity, the rejection of dogma or authority as arbiters of whose position prevails, the acceptance of ambiguity, the willingness to modify explanations in light of new evidence, and teamwork. Teachers work to incorporate these values in their classrooms so that students acquire a sense of how science communities function by being part of such a community. (See Standard V—*Sustaining a Learning Environment*.)

In facilitating classroom discussions or activities, accomplished teachers ask thought-provoking and relevant questions. Such questions stimulate a rich interchange of ideas as teachers and students test one another's assumptions, premises, and conclusions. Raising questions integrally related to the student's concerns of the moment is one path to success in this arena. A well-posed question will often permit the students to push the discussion forward. Accomplished teachers also know how to guide students to ask questions that teachers believe will lead to important learning. Because they recognize the value of post-activity debriefings, teachers engage students in discussions to tie together all the activity's elements and to ensure that students learned what they should have learned.

Teachers monitor their direct involvement in classroom discourse. They allow appropriate wait time after posing questions and after receiving responses to give students time to think. They value all contributions to a discussion, even as they coach students to probe the reasons that lie behind the opinion, and emphasize the need for credible evidence and consistency. They know when and how not to say too much and facilitate student-to-student interactions that reflect peer-to-peer discussions by scientists. Discourse in their classrooms is characterized by the kind of tentative, hypothetical, exploratory language that scientists themselves use.

Accomplished teachers are mindful that a long-term goal of science education is to cultivate lifelong learners. They understand that students need time to develop fluency

with science inquiry processes. They encourage this growth by offering their students abundant practice and, when opportune moments present themselves, demonstrations and directed instruction. For example, they might take the opportunity to talk through a science question that comes up in the course of a class discussion, "making public" the thought processes and strategies that an expert in science uses when faced with a new challenge. Accordingly, they take care to foster their students' intellectual independence—at first, modeling and demonstrating the thinking processes of a scientist for their student apprentices, but gradually making way for increasingly student-generated questions.

In pursuing an inquiry-based curriculum, accomplished science teachers take risks. They are willing to live with the sometimes unpredictable consequences of an activity- and student-centered pedagogy. They know that experiments and student interpretations of them will not always—or even very often—proceed exactly as planned. They endure the temporary frustration on the part of students as a predictable aspect of the inquiry process because they know that the conclusions students earn are lastingly their own, and that acquiring the processes of science implies experiencing all the sensations of scientists—including, from time to time, confusion.



Standard VIII: Making Connections in Science

Accomplished Adolescence and Young Adulthood/Science teachers create opportunities for students to examine the human contexts of science, including its history, reciprocal relationship with technology, ties to mathematics, and impacts on society, so that students make connections across the disciplines of science, among other subject areas, and in their lives.

Science is a way of looking at the world and interpreting it in a thoughtful, creative, and logical manner. It is an ongoing sense-making activity with deep roots in humankind's collective past and huge implications for the shape of its future. For students to see science as alive with possibilities, accomplished science teachers know that students need regular exposure to the human contexts of science. They need to learn stories from the past about the struggles, setbacks, and triumphs of individuals and teams of investigators in their quests for deeper understanding of the natural world. They need to see examples of the interdependent relationship among science, technology, and mathematics and examples of ethical dilemmas, both current and past, that surround particular scientific activities, discoveries, and technologies. They need opportunities to think about and work through the pervasive, sometimes deleterious, economic, cultural, and social changes science has induced. Accomplished teachers are aware of the origins of science and make explicit the multiple connections between its progress and the course of civilizations. Through their instructional choices, accomplished teachers invite students to explore these relationships across the disciplines instead of adhering rigidly to disciplinary boundaries.

Accomplished teachers fill their classrooms with engaging and stimulating material that students can use in their investigations of

science history. They understand that students may identify with certain groups, and they prepare materials relevant to their students. They introduce topics and issues that will entice all their students—especially girls and underrepresented minorities—to participate actively and enthusiastically in class discussions and activities. They know that the study of science history is an excellent opportunity to have their students read and write in the discipline.

Accomplished science teachers provide a complete picture of the human contexts of science. In broaching a topic, they acquaint students with stories of some of the people and major events that produced or were affected by a discovery. On occasion, they may confront students with the same intellectual problem faced by a previous investigator and ask for proposed solutions. They do so for a variety of reasons. One of the best ways for students to learn how science transpires is to encounter concrete examples that illustrate the reality, for example, that science is a collective enterprise that ordinarily grows by accretion through the contributions of many investigators operating within a stable paradigm; that paradigm shifts or revolutions are usually resisted by the scientific establishment; that scientists are subject to the same weaknesses and temptations as people in other lines of work; and that the scientific community demands reproducible proof and eventually yields to logic based on it.



Accomplished teachers also make sure that students develop a rich and diverse historical perspective about science because teachers realize that such knowledge is part of students' shared cultural heritage. These teachers emphasize the inquisitive nature of scientists, the ways scientific investigation has manifested itself in leading to scientific discovery, and the role a healthy sense of wonder plays in the lives of all people who value science. Certain episodes are so seminal to the development of modern science—for example, Copernicus's model of planetary motion displacing man from the center of the universe, Lise Meitner's early work in modern atomic theory, Charles Drew's discovery of blood plasma—that all students deserve access to them. A historical perspective makes students aware of the impressive sophistication of early civilizations, such as Chinese, Egyptian, Greek, Aztec, Incan, and Polynesian scientific thinking. Teachers incorporate and include the contributions of historically underrepresented groups, such as women, minorities, and indigenous peoples. Accomplished teachers teach their students about the impact of science on art and literature and about the universal drive in all societies to understand and better use their natural environment.

The instructional practices that characterize accomplished science teachers are also notable for their integrated quality across subject areas. Accomplished teachers have developed powerful mental schema for interpreting phenomena in terms of large interdisciplinary patterns. They actively push for interdisciplinary connections within science and with other disciplines. They might, for example, have students make connections among the disciplines of sciences by having students analyze concentrations of pollutants in water and air (chemistry) and discuss the emerging theory of sepsis (biology). A cross-disciplinary unit could be based on the writing of an author such as Charles Dickens. Students could read a Dickens novel (reading

and language arts), and they could explore the environmental issues of late nineteenth-century London (science). Students could then prepare impact studies to examine the influence that Dickens had on the decision of London magistrates to pass laws to control pollution (civics and science). They also could study the child labor laws that stemmed from scientific progress during the Industrial Revolution (social studies (history and science)).

Historically, the scientific endeavor has developed out of a fruitful union of science, mathematics, and technology. Studying the history of science tends to highlight the reciprocal relationship in the development of these three modes of thought, each of which has an essential place in the education of the scientifically literate individual. Teachers help students explore this mutual interdependence, including helping students understand the differences between science—the effort to gain knowledge about nature for its own sake—and technology—the effort to assert control over nature for the benefit of humankind—as well as the use of mathematics in both.

By engaging students in thinking critically about the interaction of technological change and society, accomplished science teachers enable students to appreciate that these endeavors provide important benefits, but that technological solutions can exist only within natural and ethical constraints; that these solutions frequently have significant and unforeseen side effects; that all technologies involve tradeoffs; and that the public—as consumers and voters—ultimately must decide which technologies to rely on as a society. Teachers share with students examples of such key advances in science and technology as those in medicine that have reduced infant mortality and extended the average life span. They also help students understand the ethical complexities of science and technology and their impact on global issues in such contemporary examples

as the human genome, cloning, weapons of mass destruction, and germ warfare.

Teachers help students understand how to use the process of science inquiry to search for information on which to base decisions in all areas of their lives. Accomplished teachers ensure that students recognize the appropriate foundation for their decisions; some decisions will be based on scientific facts, whereas others will be grounded in moral beliefs, worldviews, religion, and family and cultural values. In guiding their students in discussing the ethical issues raised by

science, accomplished teachers do not impose their own values but help their students develop the critical-thinking skills they will need to make appropriate choices in a world dominated by fast-moving changes in all the sciences. Teachers understand that critical thinking has a motivating power and intrinsic value in helping students understand the nature of technology and its influence on the quality of life.



Reflections on Standard VIII:

Standard IX: Assessing for Results

Accomplished Adolescence and Young Adulthood/Science teachers employ multiple, ongoing methods that are fair and accurate to analyze the progress of individual students in light of well-defined learning goals, and their students achieve meaningful and demonstrable gains in the learning of science. Teachers clearly communicate these gains to appropriate audiences.

Assessment—the process of using formal and informal methods of data-gathering to determine students’ growing scientific literacy—is a crucial, ongoing component of the pedagogy of the accomplished science teacher, used to inform instruction and improve student learning. It is especially important as the education profession, all levels of government, and society at large move toward requiring more tangible evidence of learning. Accomplished teachers have command of a wide range of assessment methods and strategies that align with the central goals and key concepts of the science curriculum, and they willingly hold themselves accountable for what goes on in their classrooms. They understand that their primary purpose is to advance the science learning and development of the students in their charge. They demonstrate that their students have made meaningful gains in the knowledge, skills, and attitudes relevant for their discipline, school, and district.

Accomplished science teachers understand the complexities inherent in defining learning goals and outcomes. They know that different teaching and learning contexts require tailored goals and assessments to measure student progress. They also realize that the knowledge, skills, and attitudes expected to be learned by students—including the ability to understand scientific content, design and conduct experiments, make arguments from evidence, communicate scientific information, and work collaboratively on a

team—are interrelated and may require a variety of formal and informal measurements.

Accomplished teachers use a variety of measurement tools, ranging from tests and quizzes to portfolios, interviews, and student writing such as journals, to document the meaningful positive growth in students’ science learning, and they use this information to inform their instruction. They measure advances in students’ science knowledge through a combination of assessments and along several dimensions. For some students, meaningful gains might be completing a major research project, solving a particularly complex science problem, or achieving high scores on a portfolio defense or a high-stakes test. For others, an initial gain might be a change in attitude or attendance that leads to more significant gains in science knowledge. (See Standard I—*Understanding Students*.) Accomplished teachers can also show how their students have grown in terms of other measures of student progress, such as changes in students’ behavior, communication skills, and academic discourse. In all cases, however, accomplished teachers are able to document multiple, meaningful, and positive changes that occur to the students in their classes.

In the daily practice of accomplished teachers, assessment and the daily flow of instructional activity are difficult to separate or distinguish from each other. Assessment takes place before, during, and after instruction and interacts with it in ways that are formal and informal, embedded, and

ongoing. These might include objective test methods, portfolio reviews, science projects, laboratory reports, interviews, essays, and other techniques. Portfolios in particular can be effective in gauging student progress over time, provided they are meaningful records of the natural pulse of the classroom intellectual life. Accomplished teachers systematically monitor the quality of student contributions to group discussions. They observe performances during laboratory exercises to evaluate students' reasoning, application of thought processes, and growing skills in laboratory techniques. Such teachers also record their observations of student activities and performances in a thoughtful and systematic way. For example, they observe each student at regular intervals rather than only when something unusual has happened to prompt an observation.

Teachers also recognize that the achievement of their students does not begin when they first enter the high school building. Science literacy develops throughout students' entire school careers, from early childhood through young adulthood. Accomplished teachers identify and focus on their part of the science curriculum continuum. For example, at the start of the school year, they use pre-tests to establish a baseline of their students' science knowledge; throughout the year they then use post-tests to measure students' progress. They use carefully crafted diagnostic instruments and strategies to identify students' understandings of specific science topics, beginning their instruction with a clear understanding of the starting knowledge of each student. (See Standard III—*Understanding Science Teaching*.) They also evaluate their students in terms of multiple intelligences, learning styles, and preferences. (See Standard I—*Understanding Students*.)

Teachers throughout the United States face mandated testing programs, whether at the local, district, or state level. Accomplished teachers actively seek information on the

disciplinary standards and curriculum frameworks that underlie the high-stakes tests. They also keep abreast of new testing environments, such as online assessments. They incorporate this information into their classroom science activities to prepare their students for testing procedures while helping them learn. Accomplished teachers also prepare students for external measurement methods in ways that use inquiry-based learning. They know how to acquire and use the data that large-scale tests provide, and they advocate for the appropriate reporting and interpretation of that data.

Throughout their practice, teachers integrate performance tasks that incorporate problem solving to teach students the processes of science inquiry and the values and habits of mind associated with this way of analyzing the natural and engineered worlds. Assessments devised by accomplished science teachers probe students' depth of understanding, in addition to their ability to recall facts or work an equation. These tasks require students to use higher-order thinking, deductive reasoning, and writing skills. For example, teachers might ask students to use technology resources to analyze a novel problem or work through a laboratory investigation, create a science portfolio, construct a graphic organizer such as a concept map, evaluate an ethical dilemma, or write a critical essay. These assessments might require several discrete, logical steps to solve or admit to more than one solution. They might even require a period of days or weeks to complete. Whatever their particular form, such assessments reveal to the teacher the students' thinking pattern, in light of current research-based cognitive learning theories. Teachers are able to determine when students used the right method to arrive at a wrong answer, for example, or used a flawed method to achieve a correct answer. Because these assessments are deeply informative, teachers can use them to determine the direction of future instruction.

Student understanding of assessment results plays an important part in the accomplished teacher's approach to assessment. Teachers involve students in assessing their own progress because they know the ability to self-assess fosters the growth of independent learners. Students might select which projects to include in their science portfolio and justify their choices with a reflective essay, which itself might become part of a portfolio and the basis for a student-teacher conference. Teachers might encourage students to participate in identifying criteria for group-created rubrics that could be used to assess student learning. Accomplished science teachers are completely open with students about the purpose and content of assessments, and they share with students the rubrics they will use to evaluate responses. They also return to students more than just a grade. Their feedback is rich and informative, telling students what the grade means, where they are doing well, and where they need to improve.

Accomplished teachers develop and provide to students a clear evaluation plan describing how student performance will be measured, recorded, reported, and interpreted. They address the rights of students and their parents as related to confidentiality and academic honesty. They prepare evidence-based reports of their evaluations of student progress that clearly communicate to students, parents, and administrators the kind and quality of gains—or lack thereof—in students' understanding of science. Teachers provide parents with meaningful feedback that includes examples of the kind of work their child is doing in science class and that is performance standards for students at the same developmental level. (See Standard XII—*Connecting with Families and the Community*.)



Reflections on Standard IX:

Promoting Professional Development and Outreach

This final section of *Adolescence and Young Adulthood/Science Standards* addresses those aspects of practice that guide instruction and improve teaching continually, both in the classroom and beyond: using self-evaluation and analysis (Standard X—*Reflecting on Teaching and Learning*), contributing to the continuing growth of the larger professional community (Standard XI—*Developing Collegiality and Leadership*), and recruiting home and community support for the science program (Standard XII—*Connecting with Families and the Community*).

Standard X: Reflecting on Teaching and Learning

Accomplished Adolescence and Young Adulthood/Science teachers continually analyze, evaluate, and strengthen their practice to improve the quality of their students' learning experiences.

Accomplished science teaching comes in part from experiences working with students and addressing their specific needs while regularly reflecting on how one's actions and initiatives are fostering student learning. Accomplished science teachers continually strive to become masters of their profession. They are lifelong learners who work to improve the quality of their practice. They recognize that the teaching of science is an evolving field in which some issues are settled and others remain to be resolved. They recognize that the demands of accomplished science teaching change over time; indeed, they change with each class and each student. Consequently, accomplished teachers regard themselves as working on the front line of education research. They view each year as another opportunity to improve the quality of their own teaching.

Accomplished teachers exercise seasoned judgment in coping with tough challenges that do not lend themselves to simple solutions. They experiment with new approaches and instructional strategies. They are alert to the teachable moment and are consistently able to take advantage of the unpredictable opportunities that present themselves in the course of the school day.

Teachers avail themselves of many resources in analyzing the appropriateness and effectiveness of their teaching. They seek and use feedback from students, colleagues, administrators, and parents. Other teachers, in particular, are a rich source of perspective and insight. (See Standard XI—*Developing Collegiality and Leadership*.) Accomplished teachers also share their reflections with their colleagues.

Accomplished teachers keep themselves up-to-date on significant science and education research findings, which they assimilate with the open-mindedness and skepticism of a scientist. They extend their knowledge of local, state, and national standards and of standards-based teaching strategies. Teachers read professional publications and take advantage of professional development opportunities. They add to their classroom repertoire of effective demonstrations, explanatory analogies, and activities that show the promise of intriguing and engaging students and stimulating student thinking. Their classrooms are student-centered but teacher-led. (See Standard III—*Understanding Science Teaching*.)

Teachers have a vision for their students, the dynamics of their classroom, their own teaching role, and the future of the profession.



They know, and have positions on, the major controversies in the field. They consider new pedagogical ideas and make sound judgments regarding their applicability to their own teaching. They can speak compellingly about why they make the pedagogical decisions they do and can explain the internal logic underlying the actions they take. They clarify their instructional goals to students and adapt and extend resources to achieve best practice for all their lessons.

To improve instruction and student learning, accomplished teachers gather and use extensive data from their own classrooms and from outside researchers. Accomplished teachers also advantage of the capabilities of technology in their search for data about their teaching. For example, they may videotape their teaching to later examine the components of their practice.

Teachers continually analyze and reflect on their practice, asking themselves questions such as, “Why didn’t kids understand the changing concentration when they did this titration experiment? Is it that they don’t understand the concept of titration?” and “How can we increase our students’ ability to find patterns in their ecological data?” Accomplished teachers work with their colleagues—in departmental or team meetings, in workshops and conferences, and with colleagues around the district, state, and nation—to ask questions about their

performance and that of their students and use those discussions to improve practice. (See Standard XI—*Developing Collegiality and Leadership*.)

Teachers are aware of their personal strengths and weaknesses and use this knowledge to set professional goals. For example, they can describe how their particular cultural background, biases, values, and life experiences might limit or enhance their teaching effectiveness with their particular school community, and they commit to broadening the perspectives of everyone involved.

Accomplished teachers participate in a wide range of reflective practices that reinforce their creativity, stimulate their personal growth, and enhance their professionalism. They exemplify the highest ethical and moral ideals and embrace professional standards in assessing their practice. Ultimately, self-reflection contributes to teachers’ depth of knowledge and skill and adds dignity to their practice. Accomplished science teachers ground their entire practice on a profound belief in the intellectual and academic merit of teaching. Reflection is therefore a critical element that improves and refines their professional life.



Standard XI: Developing Collegiality and Leadership

Accomplished Adolescence and Young Adulthood/Science teachers contribute to the quality of the practice of their colleagues, to the instructional program of the school, and to the work of the larger professional community.

Accomplished science teachers understand that teachers need not and should not work in isolation; rather, they should be active members of learning communities. As such, they contribute to the improvement of the practice of their colleagues as well as to the instructional program of the school and the larger professional community. They let all members of the community, including policymakers and parents, know what real science learning is.

Accomplished teachers strengthen the school as a learning community in many different ways. They are team players, committed to supporting and learning from their colleagues. They participate in the solution of districtwide and schoolwide problems. They contribute to discussions of policy, especially those related to the K–12 science continuum, in ways that demonstrate professional responsibility and advocacy without being partisan. They develop and analyze curricular materials for their department and participate in evaluating state and local science standards and high-stakes tests. They collaborate with learning specialists to ensure that students with special needs and diverse backgrounds have positive, strong, successful, and effective science learning experiences. (See Standard VI—*Promoting Diversity, Equity, and Fairness*.) They do their part in discharging administrative responsibilities. They act as science resources for colleagues in other disciplines and collaborate in the planning of integrated curricula. They understand that informal interactions and peer relationships can be as powerful as

formal mentoring structures, and that leadership emerges from either context. Finally, they articulate to students, other practitioners, administrators, families, and the community at large the virtues of science education and the forms it must take if all students are to become science-literate adults.

Teachers advance the knowledge and practice of colleagues, at the school and beyond, in several other ways as well. For example, they may design and carry out professional development activities in science, including mentoring pre-service and novice teachers. They also may advocate for securing and implementing current resources and make their colleagues aware of new uses of technology. They often take the lead in encouraging publishers to improve instructional materials; for example, they may suggest the incorporation of the latest science and science education research or the inclusion of materials reflecting diverse cultures and diverse student interests. They observe and critique the instructional approach of colleagues and, in turn, welcome their peers into their classrooms and laboratories. They share successful practices, organize workshops, or publish in scholarly journals. They may organize informal study groups to discuss important topics and research papers. They read and post to electronic discussion groups and mailing lists in their subject area. They play an active part in, and make a positive contribution to, professional organizations and may serve on local, state, or national education task forces. They may work with researchers and scientists to do science, and to make the

Standard XII: Connecting with Families and the Community

Accomplished Adolescence and Young Adulthood/Science teachers proactively work with families and communities to serve the best interests of each student.

Accomplished science teachers place a premium on connecting with families and community members in meaningful ways. They recognize the importance of establishing productive, mutual relationships with students' families. They also reach out to communities to enhance student learning. They know that the expectations and actions of families have a huge impact on the learning success of students. They respect the role of families as students' first teachers and acknowledge the high aspirations that most families have for their children's education. Early in the school year, they solicit the support of parents and other adult caregivers for the science program. Teachers are receptive and welcoming in their attitude; they establish communication with the family, seeking information from parents about their children's strengths, interests, preferences, learning goals, and home life. They are also proactive and anticipate parents' concerns. Timely response and active outreach are hallmarks of their communication activities.

Accomplished teachers provide information to families about the school science program's content, routine, and goals. They suggest actions that families can take to help their children's science literacy growth by, for example, providing a quiet place and a set time for doing homework and encouraging thinking and reasoning about everyday natural phenomena inside and outside the home. From time to time, accomplished teachers may design an intriguing science activity, challenge, or project with an eye toward

involving the whole family in thinking of solutions. Accomplished teachers inform parents about science opportunities for student enrichment beyond the school building, such as resources on the Web and at the public library, opportunities for student involvement in community science activities, and science programs after school or during the summer. Accomplished science teachers rearrange and adapt activities so that high quality instruction is available for all students regardless of the amount of parental involvement. In cases where parental support is lacking, accomplished science teachers demonstrate resourcefulness in finding ways to include parents in the education of their adolescent or young adult.

Accomplished teachers actively seek ways to disseminate information about the science program by learning what methods work most effectively in their community. For some schools, traditional outreach means—newsletters, school newspapers, parent organizations, back-to-school nights—continue to be the methods of choice. In other schools, creative approaches are needed, such as using community centers, local houses of worship, or other areas that parents frequent as venues for posting school information. Teachers learn about relevant cultural practices in their community that can affect parent-teacher communication. Because the experiences of accomplished teachers tell them that information sent from the classroom does not always reach its intended audience, they actively follow up and keep trying



to establish a reciprocal relationship with their students' families.

Teachers see parents and adult caregivers as their allies. They communicate regularly with families about their child's progress in science and respond thoughtfully to families' concerns. They explain to parents that large-scale tests are just one of many measures of their child's progress. They help parents understand and interpret test scores as indicators of achievement by providing them with concrete examples of what their child, and their child's peers, can actually do in science. Accomplished teachers provide rich reports of a student's progress that go beyond a letter grade. (See Standard IX—*Assessing for Results*.)

Accomplished teachers embrace technology as a communication tool. Voicemail and e-mail allow convenient asynchronous contact. School and classroom Web pages can both display student work and convey essential information, such as class readings and homework assignments. Accomplished teachers also recognize that not all students have computers and other types of technology at home. To give all students and their families access, they find out what outside-of-school computer resources are available, such as computers at libraries and community centers; learn about the policies governing their use; and encourage students and their families to use them. When such technological resources are difficult to access, teachers creatively use whatever resources are readily available to effectively connect and dialogue with parents.

Science class eventually brings students into contact with important topics, such as evolution, that some portions of the population may find objectionable. Teachers know how to handle criticism on these occasions; they effectively communicate with parents, respecting their private beliefs but standing up for the right of students to encounter science as a process of inquiry that is driven

by empirical evidence, but is limited by the technical instruments available to scientists at any point in time.

Teachers regard the local community as an important asset to instruction and student learning. They actively recruit families and other community members with science- or technology-related backgrounds to contribute their knowledge, skills, and experiences to instruction. In addition, they involve students in community-based science explorations at such places as local museums, parks, and businesses. This involvement can focus on doing research for intellectual satisfaction or on solving a problem, such as analyzing the quality of a local stream, doing a neighborhood energy audit, or counting buds or butterflies to monitor local populations. (See Standard III—*Understanding Science Teaching*.)

At the same time, accomplished teachers are conscious of their membership within the community. They are aware of their obligation to give back to the community and to foster in their students a similar sense of community responsibility. They encourage their students to actively participate in the world beyond the classroom and help them find appropriate outlets for their desire to help their community. Accomplished teachers set an example of community participation and involve their students in science-related activities that have an altruistic motive—for example, volunteering at the regional hospital to help in the blood testing laboratory or interning at the local Environmental Protection Administration office to help measure pollen counts. (See Standard IV—*Engaging the Science Learner*.)

Accomplished teachers see their students' families and local community as an extension of the school. They take advantage of local resources to bolster the curriculum and foster student learning.



The 12 standards in this document represent a professional consensus on the characteristics of accomplished practice and provide a profile of the accomplished Adolescence and Young Adulthood/Science teacher. Although the standards are challenging, they are upheld every day by teachers like the ones described in these pages, who inspire and instruct the nation's youth and lead their profession. By publishing this document and offering National Board Certification to science educators, NBPTS aims to affirm the practice of the many teachers who meet these standards and challenge others to strive to meet them. Moreover, NBPTS hopes to bring increased attention to the professionalism and expertise of accomplished science educators and in so doing, pave the way for greater professional respect and opportunity for these essential members of the teaching community.

In addition to being a stimulus for self-reflection on the part of teachers at all levels of performance, *Adolescence and Young Adulthood/Science Standards* is intended to be a catalyst for discussion among administrators, staff developers, and others in the education community about accomplished practice in this field. If these standards can advance the conversation about accomplished teaching, they will provide an important step toward the NBPTS goal of improving student learning in our nation's schools.

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The National Board for Professional Teaching Standards' *Adolescence and Young Adulthood/Science Standards* reflects more than a decade of dialogue about accomplished teaching in science. These standards derive their power from an amazing degree of collaboration and consensus. Through the expertise and input of two standards committees, convened ten years apart; numerous reviews by a board of directors; and two periods of public comment by educators, policymakers, parents, and the like; as well as through the intense study of candidates for National Board Certification who have immersed themselves in the first edition; these second-edition standards emerge as a living testament to what accomplished teachers should know and be able to do. *Adolescence and Young Adulthood/Science Standards* represents the best thinking by teachers and for teachers about advanced teaching practice in the field.

The National Board for Professional Teaching Standards is deeply grateful to all of those who contributed their time, wisdom, and professional vision to *Adolescence and Young Adulthood/Science Standards*. Any thank-you must begin with the pioneers in 1992, who spent five years debating, reflecting, and articulating the multiple facets of accomplished teaching, so that they could help advance the field and also provide a rigorous and sound basis for national certification of teachers. In particular, the National Board would like to show its appreciation to Chair Ann Haley-Oliphant and Vice Chair Grace S. Taylor, who so skillfully led the effort to weave the National Board's five core propositions into field-specific standards of teaching excellence.

Any field grows, shifts, and evolves over time. Standards, too, must remain dynamic and therefore are subject to revision. In 2002, the National Board for Professional Teaching Standards convened a second Adolescence and Young Adulthood/Science Standards Committee. This committee was charged with achieving both continuity and change, using the first edition of the standards as the foundation for its work, but modifying the standards to reflect best practice of the early twenty-first century. The Adolescence and Young Adulthood/Science Standards Committee exemplified the collegiality, expertise, and dedication to the improvement of student learning that are hallmarks of accomplished teachers. Special thanks go to Chair Gail Wortmann, NBCT, Vice Chair Maria Lopez-Freeman, and Facilitator Shelby Cluts, NBCT, for their invaluable leadership in making the second edition a reality. The National Board for Professional Teaching Standards also thanks Ted Willard for serving as a liaison from the American Association for the Advancement of Science and Al Byers and Eric Pakenham for serving as liaisons from the National Science Teachers Association.

The work of the Adolescence and Young Adulthood/Science Standards Committee was guided by the NBPTS Board of Directors. The National Board Certification Working Group deserves special thanks, as it reviewed this second-edition standards document at various points in its development, made suggestions about how the standards could be strengthened, and recommended adoption of the standards to the full board of directors. Representing the board of directors as liaison to the standards committee was Patricia Colbert-Cormier, whose knowledge and enthusiasm made her a valuable advisor and friend to the standards committee. She contributed significantly to the work of the committee and helped represent its views at NBPTS board meetings.

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In presenting these standards for accomplished science teaching, NBPTS recognizes that this publication would not have evolved without the considerable contributions of many unnamed individuals and institutions. On behalf of NBPTS, I extend my thanks to all of them.

Katherine S. Woodward
Director, Certification Standards
2003



The core propositions of the National Board for Professional Teaching Standards

- 1) *Teachers are committed to students and their learning.*
- 2) *Teachers know the subjects they teach and how to teach those subjects to students.*
- 3) *Teachers are responsible for managing and monitoring student learning.*
- 4) *Teachers think systematically about their practice and learn from experience.*
- 5) *Teachers are members of learning communities.*