NBPTS Early Adolescence Science STANDARDS

Second Edition

for teachers of students ages 11–15

The National Board would like to express appreciation to the U.S. Department of Education for its support for the cost of developing and publishing this standards document.

This project is funded in part with grants from the U.S. Department of Education and the National Science Foundation. Through September 2002, NBPTS has been appropriated federal funds of $119.3 million, representing approximately 45 percent of the National Board Certification project. More than $143.0 million (55 percent) of the project's cost will be financed by nongovernmental sources.

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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 Early Adolescence/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.

Preface

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.

Introduction

Science is at the heart of our existence on Earth. We live on a planet filled with life, movement, and technology, and we have long sought to understand our world and the worlds beyond. The more complex our world becomes, the more we realize that there are phenomena beyond our current understanding; and the more we seek to improve our lives, the greater our need for science literacy.

Accomplished science educators' primary goal is to develop scientifically literate students by teaching them to think like scientists, both in science class and in their everyday lives. Science educators set out to instill in students a never-ending curiosity about the world and to develop in them the skills necessary to investigate their questions. They challenge students to explore unanswered questions, test hypotheses, construct and revise models, and question innovations. They make science exciting while ensuring that students are learning.

As part of its ongoing development of the field, the science community has articulated a professional consensus on the scope of science literacy.[1] To be scientifically literate, one needs a working familiarity with (1) the nature of science, including a grasp of the various inquiry processes 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 contexts of science, including a familiarity with the history of its development and with the reciprocal relationship over time among it, mathematics, and technology and their mutual economic, political, and cultural effects on society. A scientifically literate person not only possesses knowledge of these various aspects of science but also makes use of them in ethical decision making and participation in civic life.

Teachers of early adolescents face many challenges as they advocate for high-quality science education in their schools and communities. They need to meet the increasingly diverse educational needs of their students, especially students for whom English is a new language and students with exceptionalities. They need to promote the participation of students from groups that have been historically underrepresented in the study and practice of science. They need to be familiar with current technologies while keeping the function of technology in perspective in their classroom. In the process, they may face a dearth of high-quality resources, large class sizes, colleagues who neglect the unifying concepts and "big ideas" of science, limited parent involvement, and inadequate professional-development opportunities.

While these challenges are many, perhaps the most daunting challenge facing science educators is their responsibility to contribute to the education of citizens who are able to make responsible and ethical decisions in their personal, scientific, and civic lives. The legendary "mad scientist," using his powers for evil, is no mere fabrication in a world of chemical weapons, increasingly intelligent robotics, and genetic engineering. Accomplished teachers present students with ethical challenges, and they teach the skills required for effective decision making.

Accomplished teachers respond proactively to all of these challenges, and they are supported by the science education community, which is continually creating and articulating a vision of accomplished science teaching. The National Research Council, through its development of *National Science Education Standards,* spelled out a vision for science education in the twenty-first century. The National Science Teachers Association is constantly publishing research on science teaching and learning. The American

1. See, for example, 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). See these documents for more detailed descriptions of what students should know and be able to do in science.

Association for the Advancement of Science is defining and dissecting the skills necessary to be scientifically literate, and through Project 2061 it has created numerous science resources. Contributions such as these are key to creating a scientifically literate society through a continuous, connected, science-education curriculum from early childhood through young adulthood.

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 underlying *Early Adolescence/Science Standards* 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 hands-on, minds-on science activities accompanied by regular opportunities to think about the significance of what they see and do and to develop deep understandings of important science concepts. A second assumption is that students benefit immensely when they explore science concepts that derive from or connect with their everyday experiences in the world. A third is that student insights are enriched when young people have opportunities to share and test their ideas with a larger team of investigators in the classroom and beyond.

Accomplished science teachers engage students in instructional conversation in which teachers contextualize formal, schooled knowledge with students' individual, community, and family knowledge. Teachers listen actively and adjust responses to assist students' efforts. Such conversation can reveal the knowledge, skills, values, and diverse cultures of learners, enabling teachers to adapt their teaching to fit the learner's experience base.

Developing High and Rigorous Standards for Accomplished Practice

In 1992, a committee of Early Adolescence/Science teachers and other educators with expertise in this field began the process of developing advanced professional standards for teachers of students ages 11 to 15. The Early Adolescence/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 *Early Adolescence/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 the professional consensus at this point about the essential aspects of accomplished practice. The deliberations of the Early Adolescence/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 over the next several years, *Early Adolescence/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. Teaching 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 13 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 it 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 13 standards:

I. ***Standard Statement***—This is a succinct statement of one vital aspect of the practice of the accomplished Early Adolescence/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.

Introduction

The 13 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.

Early Adolescence/Science STANDARDS

(for teachers of students ages 11–15)

Second Edition

OVERVIEW

The National Board for Professional Teaching Standards has developed the following 13 standards of accomplished practice for Early Adolescence/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 the National Board Certification in this field.

Preparing the Way for Productive Student Learning

Establishing a Favorable Context for Student Learning

Advancing Student Learning

Supporting Teaching and Student Learning

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

The first section of *Early Adolescence/Science Standards* describes areas of background knowledge—concerning students, science, and instructional resources—that accomplished teachers bring with them to the classroom. A look at the elaborations of these three standards makes clear, however, that such a description is necessarily incomplete because each aspect of accomplished practice described is continually influenced and reshaped by circumstances encountered in the classroom. Thus, although this section of the standards can indeed be seen as preparing the way for productive student learning, the knowledge, decisions, and judgments described in it are cultivated and deepened throughout a teaching career.

Standard I: Understanding Early Adolescents

Accomplished science teachers know the unique characteristics of their students and use this knowledge to determine students' understanding of science and to design and implement appropriate instruction to enhance student learning.

Accomplished Early Adolescence/Science teachers are committed to the idea that all students can learn science. Indeed, they see scientific literacy as both critically important for all students and within the capabilities of every student. They understand that the middle grades represent a kind of intellectual Rubicon in the science learning of many students;[2] it is during this period that most students effectively decide either that the scientific approach to understanding the world has enduring interest and value for them or that it is too difficult or irrelevant to their lives. Accomplished teachers are passionate and enthusiastic about involving adolescents in the excitement and satisfaction of scientific inquiry. They genuinely enjoy their interactions with young adolescents, and they frequently communicate, in word and deed, their high expectations for each student's success.

Although they know that all students can learn science, accomplished teachers are also aware that not all will do so in the same way or at the same rate. Because science learning builds on prior mental constructs and experiences, teachers differentiate their instruction to address the specific needs of each student.

Knowledge of Individual Students

In the accomplished teacher's classroom, practically everything about the student is relevant information. Teachers seek an awareness and appreciation of each student's cultural, linguistic, and ethnic background; learning characteristics; family setting; and personal interests, strengths, needs, and goals to inform their practice. They find out, for example, who among their students may have difficulty understanding English, who has a special learning need, who enjoys tinkering with mechanical devices, who has a pet tarantula, and who has been to an aquarium or tide pool with the family. They strive

2. All references to students and teachers in this document, whether explicitly stated or not, refer to early adolescent students and accomplished Early Adolescence/Science teachers, respectively.

to gain a sense of each student's science literacy history, including the degree of confidence the student shows in using the inquiry processes of science and the degree of background knowledge he or she brings to class concerning natural phenomena, the historical development of science, the relationship between science and technology, the language of mathematics, and other pertinent understandings. Accomplished teachers design their lessons by considering how students of differing abilities, experiences, ethnicities, and habits of mind come to understand science. (See Standard IV—*Diversity, Equity, and Fairness.*)

Teachers use this knowledge of their students as individual learners, together with their knowledge of science and how to teach it, to frame their practice equitably and address the needs of each student. For example, if students hesitate to take part in science learning activities, the teacher can infer several potential explanations: One student may come from a program with little previous hands-on experience; a second may be shy and unassertive; a third may have trouble with the mathematics of the activity; and a fourth may not see the connection between the activity and his or her world and thus may lack motivation to participate. Using this information, accomplished teachers effectively differentiate their instruction to engage all students and advance their learning.

Learning and Developmental Characteristics

In addition to knowledge of their students as individual learners, accomplished teachers also have a broad knowledge of the learning and developmental characteristics of this age group. They understand that adolescence is a period of rapid change—physical, social, intellectual, and emotional. Puberty is the only time in life, following birth, in which the rate of growth of the individual actually accelerates, typically in uneven bursts that tend to exaggerate differences among classmates. As a result, the range of physical stature, energy levels, emotional control, and orientation to learning that exist within a group of adolescents can be enormous.

Teachers understand that adolescents are in the midst of a social transition every bit as sweeping as the physical ones they undergo. They have begun to make the shift from an exclusively family-centered identification to a shared allegiance with the peer group. Few students of this age are truly self-assured, although many strive to act the part. Typically, adolescents are quite self-conscious, are highly influenced by peer-group opinion, and have a desire to fit in with perceived social norms; hence, it is important for teachers to keep positive role models before students to expand their sense of enfranchisement in life's opportunities. In general, adolescents vacillate between yearning for the privileges of adult independence and reluctance to leave the shelter of childhood.

From an intellectual standpoint, young adolescents become increasingly capable of higher-order thinking. In the study of science, they can develop increasingly sophisticated explanations to account for their observations; use abstract propositions, models, and symbols; and generate schema for testing their hypotheses. They begin to understand what constitutes a good experiment and, correspondingly, can begin to identify some common failings and frailties in the practice of science, such as the tendency of investigators to find evidence that supports a favored hypothesis and ignore evidence that contradicts it. In short, they are beginning to become aware of their own thought processes by thinking about how they learn, assessing the strengths and weaknesses of their problem-solving approaches, and working to improve them.

Science teachers in the middle grades recognize distinct advantages in working with this age group. If the propensity of many adolescents is to question authority, that tendency can be profitably channeled by having students repeatedly ask one of the fundamental questions of science: "How do we know that's true?" If students in the middle grades are seeking a measure of independence, teachers can support students in conducting their own increasingly systematic and sophisticated investigations. Students of this age have an abundance of energy that can motivate their science learning when they perceive that the matters they explore relate directly to their concerns, questions, and goals in life.

Teaching Early Adolescents

Accomplished science teachers design and select instruction that addresses the developing adolescent's needs and concerns, consequently reinforcing the real-life connections inherent in science education. Teachers of this age group frequently point out the connection between the basic scientific and technological concepts under study and their actual and potential repercussions in the real world. Teachers are aware of the misconceptions, preconceptions, and alternative conceptions that young adolescents typically bring to a given topic. They take these into consideration when framing activities that lead students to question and evaluate their beliefs.

Accomplished teachers are expert in adapting learning activities to the level of cognitive sophistication that students can support and in fostering greater consistency in students' sense-making efforts. (See Standard VII—*Understanding Science Pedagogy.*) Using their knowledge of students, teachers constantly interpret students' responses to science learning activities to monitor whether learning is progressing satisfactorily, and they use a variety of assessment practices to gauge instructional effectiveness. (See Standard X—*Assessment.*)

Reflections on Standard I:

Standard II: Knowledge of Science

Accomplished science teachers have a broad and current knowledge of science, along with in-depth knowledge of one of the subfields of science, on which they draw to set appropriate learning goals for their students.

Accomplished Early Adolescence/Science teachers exhibit as the foundation of their practice a broad body of knowledge. With a solid grasp of this body of knowledge and of the effective methods by which to communicate it to students, teachers are well prepared to meet the needs of all students while working toward measurable class outcomes. Given the extraordinary vastness of the domain of science, the question arises: What is the knowledge base an accomplished science teacher must command?

Accomplished science teachers are role models who exhibit all the dimensions of scientific literacy. They are literate in (1) the nature of science, including its modes of inquiry, habits of mind, and attitudes and dispositions; (2) the concepts, themes, principles, laws, theories, vocabulary, terminology, and factual information that demarcate the body of knowledge in the earth, environmental, and space sciences; life sciences; and physical sciences; (3) the historical, intellectual, social, and cultural contexts out of which science and technology have developed and in which they function today; (4) the nature of technology, the challenges it poses to human ingenuity, and its role in shaping the constructed environment, human interaction, and daily life; and (5) the current research in science and in science education.[3]

Accomplished science teachers are lifelong learners, eager to add to the edifice of their own scientific knowledge but, whenever data and logic support doing so, are equally ready to tear down demonstrably incorrect ideas and build anew. Teachers encourage the free expression of ideas and practice the notion at the heart of the scientific enterprise: "May the best argument supported by the most compelling evidence win."

Nature of Science

Accomplished teachers have a thorough grasp of science as a sense-making activity, that is, as an approach to building a consistent, testable set of understandings about how the natural world works. They recognize which kinds of questions fall within the purview of science and which do not. They are aware that there are other ways of interpreting the world that have value and deserve respect, but they believe the processes of science have a rigor and predictive power all their own to which all students deserve access. At the same time, teachers know that the development of scientific literacy is a long-term process. They guide and support students in their sense-making efforts by posing questions and building conceptual understandings about the functioning of the natural and engineered worlds, which is more important, at this stage of students' intellectual development, than mastering specialized, technical vocabulary. Accomplished teachers know what a scientific experiment looks and feels like. They have a clear sense of the various strategies scientists might use to frame an inquiry and open up 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

3. 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). See these documents for more detailed descriptions of what students should know and be able to do in science.

endeavor; and of the public nature of science, which needs to be communicated to and shared with others if its value is to be realized. Teachers are skilled in communicating scientific information and results of laboratory investigations with clarity and accuracy.

Having a clear understanding of the nature of science is essential at every level of elementary, middle school, and high school science teaching. It is essential because, as Henri Poincaré 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."[4] Students must experience the vitality of science in school in order to regard science as a powerful way of looking at the world, one that is capable of answering questions that matter to them. Only teachers who understand how science works, who appreciate the role of skepticism and the requirement for proof in science, who recognize how the paradigms for interpreting natural phenomena have changed over time, and who embody the openness to competing ideas characteristic of first-rate scientists can model its processes, values, and habits of mind in the classroom. And only teachers who understand the inquiry process can involve students in doing their own consistent, strategic, and legitimately scientific investigations. (See Standard VIII—*Science Inquiry.*)

Ultimately it is a classroom of actively engaged learners that marks accomplished science teaching. (See Standard VI—*Learning Environment.*) For accomplished science teachers, the point of departure for establishing such a productive learning climate is a deeply structured knowledge of the nature of science and the inquiry process.

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

Fundamental Ideas of Science

Accomplished science teachers possess a sure grasp of the core laws, principles, theories, themes, facts, and ideas that constitute the body of scientific knowledge and the associated vocabulary and terminology. They know the main tenets of the science they teach and, in overseeing students' exploration of specific topics, ultimately bring students to intellectual closure that is valid, consistent, and logically supported. Science is a collaborative social enterprise that builds on the achievements of previous generations. Accomplished teachers are conversant with the major conceptual paradigms that researchers have developed over the years in the core science disciplines and use that knowledge to inform their practice. The breadth of their knowledge base, organized by discipline, includes a firm understanding of the following aspects of science:

Earth, Environmental, and Space Sciences

Accomplished science teachers understand the origin, composition, and structure of the universe and the motion of the objects in it, including the uniformity of materials and forces found everywhere in it; the motions of the earth and the materials and systems that compose it; the processes that shape the earth's surface and the relation of these cycling processes to the environment; and the connections among environmental, economic, and social issues.

Life Sciences

Accomplished science teachers understand the diversity and unity that characterize life; the genetic basis for the transfer of biological characteristics from one generation to the next; the structure and function of cells; the life cycle, particularly in reference to the human organism; the dependence of all organisms on one another and on their environment; the cycling of matter and flow of energy through the living environment; and the basic concepts of the evolution of species.

Physical Sciences

Accomplished science teachers understand the basic properties of matter and the principles governing its interactions; the forms energy takes, its transformations from one form to another, and its relationship to matter; the nature of motion and the principles that explain it; the nature of atoms and molecules and the behavior of and interactions between them; and the forces that exist between and within objects and atoms.

These key science topics compose the heart of well-regarded K–12 school science curricula. It is axiomatic that science teachers at all levels must know the fundamental laws, concepts, and theories of science that they must inculcate in students as a condition of high school graduation. At the same time, the answer to the question of how much an accomplished science teacher should know about these essential topics should be phrased in terms of the usefulness of that knowledge as applied in the middle grades.

In all cases, the overall coherence of the science teacher's understanding of a topic—not mere recall of fact—is most valuable. The knowledge base of accomplished science teachers is notable for its integrated quality. Such teachers do not simply remember isolated bits of information; rather, they have developed schemas for interpreting phenomena in terms of larger disciplinary and interdisciplinary patterns. For example, they have a working knowledge of major unifying concepts and processes—cause and effect, patterns of change, systems and interactions, structure and function, and so on—derived from the various science disciplines, and use this knowledge to forge links to students' prior learning, both within the science domain and across the entire middle-grades curriculum. They possess a rich repertoire of materials, experiments, demonstrations, analogies, and metaphors appropriate for use with the age group they teach. They are aware of typical commonsense understandings young adolescents have concerning specific science topics and know how to lead students to examine critically and, eventually, to discard their misconceptions. Aided by their knowledge of the typical misconceptions, puzzlements, and conceptual difficulties of the age group, accomplished teachers use their entire instructional repertoire to involve students in doing science and in constructing satisfying and complete explanations of natural phenomena.

While all accomplished science teachers can be expected to have this foundation of scientific knowledge that cuts across the disciplines, they also have in-depth knowledge in a single discipline. Hence, such teachers demonstrate a depth of knowledge about the earth, environmental, and space sciences; life sciences; or physical sciences. Consider a brief illustration of this idea within a unit on clouds and precipitation. Accomplished science teachers should know the origins of water vapor in the atmosphere; the principles of condensation and convection; the characteristics of different types of clouds and the weather conditions associated with them; and the causes of acid rain. Teachers specializing in the earth, environmental, and space sciences would also know in greater detail the effects of natural phenomena, such as the emission of oxides of sulfur and nitrogen from volcanoes on atmospheric pollutants. Teachers specializing in the life sciences would have a deeper knowledge about the specific effects of acid rain on various parts of ecosystems. Teachers specializing in the physical sciences would know more specifically how acid anhydrides dissolve in water and react with carbonates and metals.

Contexts of Science

Accomplished teachers understand science as an expression of the deep human impulse to explore and learn ever more about the natural world. They recognize the contributions of

many cultures in both ancient and modern times to the development of the scientific world picture. They are aware of the interdependent and reciprocal relationships that have occurred over the centuries marking the advancement of technology, mathematics, and science. They understand that science and technology exercise enormous influence in human affairs and are aware of the unforeseen consequences and social, political, and ethical dilemmas that frequently attend such change. (See Standard IX—*Contexts of Science.*)

Nature of Technology

Accomplished science teachers understand the role and contribution of technology in the development of human culture. Given the centrality of technology to modern life, they link its study to the study of science. Accomplished teachers understand the relationships between science and technology, that technology is ultimately a product of science, and that technology consists not only of tools, but also of processes, designs, and products. They know that people use the tools of technology to mold the world in ways responsive to their needs.

Accomplished teachers know how to use technology in ways that stimulate questions, thinking, and insights into science. They know how to integrate in their classrooms issues of design, use, and evaluation of technology in ways that illustrate how technology raises practical problems, expands possibilities, extends thoughts, and contributes to humanity. At the same time, they help students begin to recognize, understand, and appreciate the complexities of the influence of technology—its benefits and costs in human, economic, and environmental terms, and the questions it poses. (See Standard III—*Instructional Resources.*)

Reflections on Standard II:

Standard III: Instructional Resources

Accomplished science teachers are innovative in their ability to select, adapt, and create instructional resources, including print, technology, laboratory, and community resources, to support active student explorations of science.

A variety of instructional resources—including print materials, technology, and the community—helps students make the connections among the study of school science, their lives, and the world of science. Accomplished science teachers select, adapt, create, and use a diverse array of instructional resources to engage students in meaningful learning. They research, choose wisely among, and make optimal use of the instructional resources they secure.

Print Resources

Accomplished teachers know that printed materials serve as important aids to students' growth in science literacy. They use these materials selectively to support carefully planned curricular goals, instructional strategies, and ongoing assessments. They have clear criteria for evaluating the quality of printed materials, including such factors as the developmental appropriateness of the topics treated in the text; the reading levels of the materials; the accuracy and depth with which text and illustrations handle a limited number of topics; and the narrative's recognition of the historical contributions of both genders, diverse individuals, and many cultures to the developments of science and technology. Accomplished teachers provide a variety of materials in their classrooms, assist students in their comprehension and interpretation of those materials, and are able to direct students to additional information on topics of scientific interest to them. They invite students to read a wide variety of reference resources and other written materials, including biographies of a representative cross-section of scientists and inventors, science periodicals, monographs, science dictionaries and encyclopedias, outstanding essays, and literary resources.[5] In addition, they assist students in identifying and accessing appropriate resources found both at school and in the larger community.

Laboratory and Technology Resources

Accomplished teachers know how to use an array of instructional and laboratory tools to contribute to students' active science investigations and understandings, helping them to ask and refine questions, debate ideas, collect and analyze data, and draw conclusions. Traditional equipment, such as test tubes, scales, thermometers, and metersticks, has long had a prominent role in effective science programs. Instructional technology devices such as calculators, computers, probeware, data-collection interfaces, videodiscs, and CD-ROMs are increasingly available and useful.

Accomplished science teachers capitalize on the laboratory resources they have available. They know how to determine which resources will be most effective in engaging students in active learning. Many times an idea can be addressed by an activity using household materials, such as string, masking tape, or balloons, rather than an expensive

5. Possible examples of literary resources include: George, Julie Craighead. *Julie of the Wolves* (New York: HarperTrophy, 1974). Hickam, Homer. *Rocket Boys, A Memoir* (aka *October Sky*) (New York: Delta, 2000). Eckert, Allan W. *Incident at Hawk's Hill* (New York: Little, Brown & Co., 1995).

piece of equipment. Accomplished science teachers recognize the need for providing students with appropriate laboratory equipment for quality learning experiences.

Accomplished teachers also incorporate available technology into their instructional plans. Technology, properly employed, can provide conduits to facilitate learning for students. The tools of technology have many applications in the modern science classroom.[6] They can store and retrieve images, sound, and data; artificially mimic ideal conditions or otherwise allow the simulation of prohibitively dangerous experiments; and accurately record via probes and graphic displays small changes in very fast or very slow phenomena. Historical events or activities at a distance can be witnessed and worked on via telecommunications networks. For example, students from different areas of the country have exchanged information over a computer network about the pH of rainfall in their localities, leading to productive insights about weather patterns, air pollution, and energy pathways. Similarly, the use of digital cameras and presentation software has allowed students and teachers to bring their own extramural projects and experiences into the classroom for discussion. Accomplished teachers understand both the potential and limitations of technology.

The rapid increase in the availability of information that can be accessed by teachers and students provides new challenges in selecting resources. In addition to engaging in an ever-widening selection process themselves, accomplished science teachers show students how to identify, retrieve, evaluate, use, and synthesize information from multiple sources. Particularly in the case of the Internet, they know and share with students numerous ways of determining the credibility of information.

Accomplished teachers actively seek to have students take advantage of these rapidly evolving tools of technology, not for their own sake but for the ways that these tools aid understanding. Teachers know that science results from making sense of information, not from the information itself. They use technology resources to engage in ongoing professional development and lifelong learning. Where such technology is unavailable, they become strong advocates for changing this state of affairs. (See Standard XII—*Professional Collaboration and Leadership.*) They advocate for equitable access to technology resources for all students.

6. See, for example, International Society for Technology in Education. *National Educational Technology Standards for Students—Connecting Curriculum and Technology* (Eugene, Oreg.: International Society for Technology in Education, 2000). CEO Forum on Education and Technology. *School Technology and Readiness Report* (Washington, D.C.: CEO Forum on Education and Technology, 1997, 1999, 2000, 2001).

Community Resources

Accomplished teachers recognize that the local community is an important resource for the enrichment of students' science experiences. Teachers may take students into the classroom of the outdoors or into local science- or technology-related facilities—museums, hospitals, farms, power plants, laboratories—and engage them in noticing, describing, and asking questions about what they observe. Teachers actively recruit families and other community members with science- or technology-related backgrounds to contribute their knowledge, skills, and experiences to the instructional program. In addition, teachers encourage students to take responsibility for pursuing their own science-related interests in the community by, for example, attending field trips, listening to guest speakers, and becoming enrolled in extracurricular activities that broaden students' science horizons. In general, accomplished teachers see their local community as an extension of the school and take advantage of local resources to bolster the curriculum and enhance student learning. (See Standard XI—*Family and Community Outreach.*)

Reflections on Standard III:

Establishing a Favorable Context for Student Learning

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

Standard IV: Diversity, Equity, and Fairness

Accomplished science teachers take steps to understand and value the diversity of all students, promote equity in the classroom and beyond, and uphold fairness in their daily interactions with all students.

Accomplished science teachers know that providing each student with equitable access to an empowering science education requires responding effectively to diversity, finding and building on individual strengths, and acting fairly toward all students. They know that students from particular groups, including, but not limited to, female students, students of color, students of low socioeconomic status, students with disabilities, and students with special learning needs, historically have been discouraged and excluded from the sciences, both in academia and in the world of work. Accomplished teachers recognize that young adolescents must learn to see science as a way of knowing and understanding that has meaning and relevance in their lives. Science teachers find ways to use the diversities found in science, such as the diversity of life, diversity of ideas, and diversity of perspectives, to teach students to value diversity. Accomplished science teachers help students appreciate diversity in their peer group, their community, and the world.

Valuing Diversity

Accomplished teachers understand and demonstrate that they value the diversity of their students. Valuing diversity within the classroom is defined as the appreciation of students' cultural, linguistic, religious, regional, and ethnic heritage; family configuration; socioeconomic status; sexual orientation; gender; personal appearance; physical and cognitive exceptionalities; prior learning or literacy experiences; learning style; and personal interests, needs, and goals. In valuing diversity, teachers model and teach respect for all individuals and groups. Teachers highlight the diversity as well as the commonalities among students and build on them as sources of strength for the learning community. As a result, students acquire an understanding and appreciation of their own and other cultures and develop cultural sensitivity.

As an integral part of their instruction, accomplished teachers develop and use materials and lessons that reflect the diversity and multicultural aspects of students and provide appropriate cross-cultural activities. They celebrate the diversity of language forms and dialects in the United States, but they also understand that having a shared form of English facilitates communication across societal divisions. They also help students learn about different cultures within their schools, their communities, and the broader global community. Teachers use their knowledge of diverse cultures and contexts to adjust their instruction appropriately.

Accomplished teachers seek opportunities to provide forums where experiences can be shared and mutual understandings of similarities and differences can be deepened. They are particularly sensitive and responsive to family and cultural issues that affect students' attitudes toward learning. They build on the strengths of all students and are sensitive to each individual in doing so. They know that every student comes to school with a unique set of experiences, personal history, and knowledge of the world. They use examples derived from students' cultures, communities, and home environments to constantly demonstrate the relevance of science and technology to all students of all backgrounds. (See Standard I—*Understanding Early Adolescents.*)

Accomplished teachers are aware that science may feel unfamiliar to certain students—not just intellectually, but socially, culturally, and emotionally. They have a broad knowledge of the history of science and technology, and they know and appreciate the significance of scientific developments from various cultures. They help students see that individuals from all ethnic groups and cultures as well as both genders have always possessed the basic human drive to understand the natural environment. Accordingly, they make sure that all students, particularly from historically underrepresented groups, frequently hear and receive the message that people like themselves have excelled in science and that, therefore, they also can excel without sacrificing their group identity. Teachers share with students role models of successful scientists and technological innovators from diverse backgrounds.

Promoting Equity and Fairness

Accomplished teachers promote equity in their classrooms and inclusion of all students in the least restrictive learning environment. Promoting equity is defined as a deep commitment to justice and impartiality; however, equitable does not necessarily mean equal. For example, teachers recognize that not all students have equal access to computers at home or at school and are prepared to make accommodations for those students. They realize that all students need equitable access to learning and educational opportunities, and they clearly understand that it is their legal obligation to provide instruction and environments that promote equity. Accomplished teachers create instructional settings that promote learning for all students. They know how to work with students with diverse learning needs, including students with exceptionalities and students for whom English is a new language. They also know how to work closely with available specialists to ensure that all students receive the support they require to learn.

Accomplished science teachers take steps to create an atmosphere of full inclusion to ensure that all students participate fully in the study of science. They have a strong commitment to the idea that every student can learn and make progress in science, and they use adaptive strategies that enable each student to contribute and achieve. They seek the support they need to modify and adapt teaching strategies on an ongoing basis, thus providing a quality educational experience for all students. They expect each of their students to work hard, and they communicate high expectations to them. In their classes no student disappears.

In the classroom setting, accomplished teachers carefully monitor the participation of students in groups, making sure all have an equitable opportunity to participate in key roles, such as planners, leaders, data collectors, and reporters. They adjust group membership or dynamics as needed. By fostering the engagement of all students in the discourse of the classroom, they not only

serve important equity objectives but also provide opportunities for students to hear the ideas of their peers, think deeply about the validity of their own ideas, and gain a fuller understanding of important scientific ideas. These teachers are also strong advocates for students who require special accommodations in order to participate fully in classroom or lab activities.

Teachers are particularly alert to the subtle messages many girls pick up during early adolescence. They encourage their female students to take full and active roles in science: to make predictions, ask questions, offer theories, defend their positions, and, in general, assert themselves by speaking up. They create an equitable learning environment in their classrooms through seating arrangements, by virtue of whom they call on or ask to assist them in demonstrations, through the design of lab activities, and by balancing their classroom strategies to enfranchise girls. The career information that teachers provide explicitly portrays the wide range of engaging jobs available to scientifically literate females.

Accomplished teachers realize that language itself may limit students' participation in science class, so they ensure that students for whom English is a new language have full access to the science curriculum. They provide helpful nonverbal cues to meaning by using sensory aids to illustrate important points, use a natural speech rate with clear enunciation, choose their words appropriately and carefully, and frequently restate important points. They carry out regular comprehension checks to confirm that students are following the concept under investigation. When introducing new topics, they ask students to brainstorm what they already know, and then build on that foundation, offering multiple communication options for those whose command of English is limited.

In their instructional decisions, teachers address the exceptional needs of special student populations whose development falls outside the range typical for their age group or who—for a variety of reasons—learn in ways significantly different from other students. In addition to taking their own steps to accommodate students with exceptional needs, they seek appropriate help from students' families and specialists, and they advocate for essential support services to promote maximum success. They strive to meet the needs of all students while maintaining commitments to high standards and to meaningful and challenging classroom experiences.

Accomplished teachers uphold fairness in their daily interactions with students. They are cognizant of their own biases, reflect on how their biases affect their teaching practice, and strive to rectify biases that emerge inadvertently. For example, they do not favor students who frequently participate actively in class and ignore those who do not. They also help students recognize their own biases and work proactively to counter the influence of their prejudicial behavior. In this way, accomplished science teachers collaborate with students to ensure a bias-free learning environment that values diversity and promotes equity and fairness.

Reflections on Standard IV:

Standard V: Engagement

Accomplished science teachers engage students in science through creative and innovative experiences.

Accomplished teachers are passionate about science and exhibit genuine enthusiasm in teaching. They are lifelong learners who are excited about investigating the natural world. They are guides and facilitators who provide experiences that foster an understanding of science and an excitement about learning. Their students perceive the study of science as a continual source of satisfaction and intrigue.

One of the clearest indications of accomplished teaching in any discipline can be found in the response of students. Accomplished science teachers engage students in building, exploring, discussing, evaluating, and applying knowledge of the natural and engineered worlds. Their students creatively solve problems, offer ideas, pose and respond to stimulating questions, listen attentively to the solutions of peers, and, in general, display their involvement in and enjoyment of the inquiry process. (See Standard VIII—*Science Inquiry.*) These teachers know that early adolescents are at the critical age where they decide the extent to which science is relevant and interesting to them, and consequently choose to continue or discontinue future science education or exploration.

Accomplished teachers choose activities and topics that directly relate to the interests and experiences of adolescents. For example, because teachers know students of this age are intrigued by the changes in their own bodies, they regard human reproduction as an introduction into the study of genes and reproduction in plants and animals. Capitalizing on student interest in inherited traits can eventually lead to discussion and learning about the ways living things change over time. Because teachers know that adolescents frequently have an awakening concern for social issues, they may focus instruction on meaningful topics in health, business, or life skills that students care about and perceive as important to themselves and society at large. They may frame the investigation of a scientific principle—such as the conversion of chemical energy—into mechanical work in terms of a common technological application—such as the car engine—and attendant modern controversy—such as the greenhouse effect triggered by the burning of fossil fuel.

In making the connection between science learning and the interests and experiences of adolescents, accomplished teachers engage students in thinking about and exploring scientific issues rather than simply presenting a science topic. For example, teachers may utilize the novelty of a natural phenomenon or of a discrepancy between what students expect to see happen and what actually occurs to promote students' interests. Teachers then guide and support students as they begin to take over the inquiry and sustain it in a direction of their own choosing. Teachers can demonstrate the utility of science learning to this age group by frequently presenting viable career options—such as nursing, farming, science teaching, and forensics—that require a scientific orientation. In essence, science is presented as a way of knowing how and why things happen that significantly increases an individual's value in society.

Accomplished science teachers know that genuine achievement motivates students to continuously strive to do their best. At the same time, they understand that the threshold of success may vary from student to student.

To accommodate those differences, they provide many ways into a learning experience—for example, by choosing open-ended activities that allow each student to participate at his or her own pace. 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 develop students' mathematics fluency. (See Standard IV—*Diversity, Equity, and Fairness.*)

Reflections on Standard V:

Standard VI: Learning Environment

Accomplished science teachers create stimulating and safe learning environments that foster high expectations for the success of all students and in which students experience the values inherent in the practice of science.

Enhancing the quality of human associations—how students interact with each other and with the teacher—is a significant aspect of creating a productive learning environment that favors the academic as well as the social and ethical growth of students. Accomplished teachers deliberately foster a classroom culture in which students play active roles as science investigators in a mutually supportive learning community.

Physical Environment

Accomplished science teachers create a productive learning environment through effective organizational decisions. They manage the classroom efficiently, knowing how to make the most of limited resources.

Teachers recognize the value of time management in their classrooms. They establish patterns and routines that are orderly and efficient to maximize student time on task, such as methods for procuring materials for lab experiments, policies for managing a lab notebook, and procedures for submitting assignments.

Accomplished science teachers create an aesthetically pleasing and inviting atmosphere in their classrooms. Walls, bulletin boards, chalkboards, whiteboards, and displays enhance the concepts students will explore throughout the year. Teachers maintain the neat and professional appearance of these visual displays and change them to stimulate students' interest in the curriculum.

Accomplished teachers arrange their classrooms so that students can easily, safely, and productively move from independent work to cooperative groups and to the laboratory. They are sensitive to the special needs of students and arrange desks and materials with those needs in mind.

Accomplished teachers make students aware of their responsibility to follow proper safety procedures inside and outside the classroom, and ensure that they do so. Accomplished teachers review safety procedures and protocols before learning experiences, such as laboratory work and field trips, and focus on specific safety issues relevant to the upcoming task. They instruct students in and enforce standard practices regarding the use of safety equipment, such as the use of eye-protection devices.

Interpersonal Environment

From the outset of the school year, accomplished teachers foster a sense of community by encouraging student interactions that show concern for others, by demonstrating high expectations, by involving all students in the practice of science, and by dealing constructively with socially inappropriate behavior. They invite students to function as part of the learning community by involving them in tasks that develop teamwork and that require them to recognize the dynamics of their interactions with their peers.

Accomplished teachers have high expectations for the growth in science literacy of each of their students. They welcome and value the ideas of all their students. They envision success for students that students might not envision for themselves. They know when to praise and when to push. They communicate in both explicit and nonverbal terms that they admire persistence in solving problems and expect that each student will display that quality.

Accomplished teachers understand that student conduct is largely a function of student engagement. When students are interested in what they do in school, the learning environment becomes, in many respects, self-governing. By organizing science class so that it derives from students' own questions, experiences, and choices, science teachers create a dynamic that favors learning. (See Standard V—*Engagement.*)

Accomplished teachers recognize that the emotional response of some students to a lively, argumentative, inquiry-based classroom might be a reluctance to venture an opinion or idea, thereby avoiding the risk of public failure. Consequently, they work diligently to establish a congenial and supportive learning environment in which students feel safe to take intellectual risks and share ideas openly.

Perhaps most central to the process of creating a favorable learning environment is the personal example that accomplished teachers set by getting to know their students both as learners and as individuals. Accomplished science teachers know their own personal strengths and abilities in working with students and they develop them to their maximum capabilities. They are friendly, curious, and interested in the pursuit of science. They are receptive to each student's contributions to the learning process. They are active listeners and are open to new ideas. Accomplished teachers also extend themselves to students, recognizing that personal contact affects students' dispositions toward teachers, subjects, and classes. Accomplished teachers have a healthy sense of humor and a genuinely caring, respectful attitude toward students. They attend schoolwide and community functions and make themselves available outside of class to work with students or engage in informal conversations.

Accomplished teachers make instructional grouping decisions consonant with their convictions about inclusion and building community. (See Standard IV—*Diversity, Equity, and Fairness.*) They are equally comfortable employing whole-class, small-group, one-on-one, peer-coaching, or other clustering arrangements, depending on the instructional purpose at hand. For example, they frequently employ heterogeneous small-group interactions because such settings allow a great number of students to play active roles in the learning process and bring students of differing backgrounds into contact with one another. Accomplished science teachers know when each grouping method is most appropriate and can articulate their reasons for the strategy chosen at any particular moment.

Science Values

Accomplished teachers help students internalize the values inherent in the practice of science by relying on those values to shape the culture of their learning communities. Ideally, these values include such qualities as risk taking, persistence, flexibility, wonder, curiosity, openness to new ideas, skepticism, demand for repeatable proof, respect for reason, honesty, objectivity, rejection of autocracy, acceptance of ambiguity, willingness to modify explanations, cooperativeness with the scientific community, respect for all living things, and adherence to an ethical code.

Collaboration among scientists and other professionals in the pursuit of knowledge and truth is critical to the integrity of the scientific community. Accomplished teachers promote

collaboration as part of their instructional strategies. In addition to collaboration within and among student groups, teachers seek out opportunities to involve the larger scientific community in their instructional goals.

Teachers embrace the inclusion of diverse ideas within the scientific community and create learning situations that demonstrate this diversity. For example, teachers may organize discussions in their classrooms that include the subjects of human and animal cloning, preservation versus utilization of natural resources, and consideration of the benefits and harmful effects of using pesticides and chemicals in agriculture.

Because scientists are natural risk takers, experiments often produce unexpected results, which accomplished teachers view as opportunities for gaining understanding, rather than viewing them only as mistakes. For example, teachers may conduct science demonstrations that yield results that differ from the expected and build upon such occurrences to teach more about the scientific process.

Individual scientists have a strong incentive to be as accurate, objective, honest, flexible, and skeptical of their own conclusions as possible, while maintaining their curiosity and sense of wonder. When results do not fit norms or expectations, they are used to generate new questions for exploration. Accomplished teachers help students understand that science makes progress by establishing a new consensus based on the strength of evidence and logical reasoning.

Reflections on Standard VI:

Advancing Student Learning

The following standards focus on the impact that accomplished science teaching has on advancing student learning. Effective science instruction is presented in terms of four central aspects: a knowledge of instructional strategies and interdisciplinary approaches as they pertain to science education (Standard VII—*Understanding Science Pedagogy*); experience with the science inquiry process including the attitudes and habits of mind that are necessary for scientific investigation (Standard VIII—*Science Inquiry*); an awareness of the contexts of science, including the history of its co-evolution with technology and impact on civilization (Standard IX—*Contexts of Science*); and techniques for assessing student progress and the acquisition of science literacy (Standard X—*Assessment*).

Standard VII: Understanding Science Pedagogy

Accomplished science teachers understand and use a variety of instructional strategies to enhance student learning and help students make real-world connections from their scientific explorations.

Science is best taught within the context of an articulated K–12 curricular structure. Such an organizing template for instruction helps reduce one of the banes of school science—the excessive repetition of material from one year to the next without a concomitant deepening of student understanding. Accomplished science teachers coordinate their instructional program so that students' explorations of science are integrated with their experiences in the language arts, mathematics, social studies/history, health education, physical education, the visual and performing arts, career and technical education, and other essential areas of the school curriculum. In districts that do not have an articulated K–12 science curriculum, accomplished science teachers work toward the establishment of one.

Educational goal setting is an interactive process in the accomplished teacher's classroom. Often, what students should know and be able to do already have been defined broadly by district, state, and national standards. Using these guidelines as a backdrop, teachers establish long-range learning goals that are attainable and worthwhile, and that make sense for their students. They then organize, structure, and sequence learning opportunities that support these goals. At the same time, however, these teachers are flexible and resourceful in their approach to educating students.

Scientific work is ideally carried out within a cooperative social framework of peer investigators critiquing and then building on each other's cumulative achievements. Learning is maximized when students and teacher engage in dialogue while working jointly. In such dialogue, accomplished science teachers assess individual students' abilities and provide the assistance necessary for students to accomplish a given task.

Instructional Strategies

Accomplished science teachers recognize the need to provide students with access to concepts, themes, principles, laws, theories, terminology, and factual information without burying them under an avalanche of esoteric detail. They do so by relying on several simplifying strategies, such as questioning students about their relevant personal and prior experiences and knowledge in science and providing bridges to more complex scientific concepts.

In making curricular choices, teachers focus on fostering in students deep understanding of a few topics rather than superficial familiarity with a large number of topics. Clearly, there would not be enough time in a human lifespan, much less within the restricted confines of the K–12 years, for the individual student to rediscover alone all the existing and emerging concepts, laws, and theories of science with which an educated person should be familiar. Thus, accomplished science teachers constantly balance two complementary responsibilities: encouraging students' independent explorations in science and guiding students toward an expanded scientific knowledge base.

In deepening students' scientific knowledge, accomplished science teachers are also aware of the structural misconceptions that students bring with them when encountering a specific science topic. For example, many young adolescents intuitively believe that an object in motion requires a continuous applied force in order to stay in motion; that plants take their nourishment from the soil; or that only one image can be seen in a mirror at a time. Accomplished teachers often anticipate the misconceptions that accompany a given topic and take steps to help students recalibrate their thinking through appropriate activities that show the discrepancy between their naive conception and a more scientifically appropriate explanation. In redirecting students' thinking, teachers provide sufficient discussion opportunities and time for students to make new constructs their own. At the same time, accomplished teachers are sensitive to how students' cultural and personal backgrounds may affect their view of scientific discoveries, such as when families have religious differences with the key principles of evolution.

Accomplished teachers use a variety of instructional strategies to acquaint students with the major ideas of science. Through lab experiments, field experiences, physical models, mental models, simulations, and other activities, they involve students in conducting their own scientific investigations. (See Standard VIII—*Science Inquiry.*) They inform students through a rich variety of readings—both assigned to the whole class and selected independently by students—that extend, contextualize, and enrich students' hands-on experiences. They carry out demonstrations that dramatize underlying scientific principles. They select and use excellent, scientifically pertinent, and interactive uses of educational technology. (See Standard III—*Instructional Resources.*)

In implementing learning experiences, they are sensitive and responsive to the interests students bring with them to school. Accomplished teachers willingly improvise, taking their cue from newspaper headlines, local controversies, or unpredictable events that become occasions for scientific explorations that directly tie school learning to everyday life. Accomplished science teachers frequently refer to current research in science and science education, as well as their knowledge of the development of the early adolescent, to support student development of scientific concepts, theories, and skills. Accessing research promotes a thoughtful and reflective approach to appropriate strategies that help the accomplished teacher dispel myths and misconceptions that early adolescents often bring with them into the science classroom.

Teachers place technology alongside science as they create opportunities for students to investigate the laws of nature, experiment with different designs, and construct models. They help students gain facility with the tools of measurement and observation, and they pose problems centering on technology applications in communications, transportation, and manufacturing. Students learn the effects of science and technology as an outgrowth of daily events in their lives. For example, rain, sunshine, and snow all present opportunities to discuss, design, or construct forms of protection from the elements and to evaluate ways of coping with weather-related problems. A trip to any nearby body of water might offer a chance to design a variety of floating structures and test original theories of buoyancy. Daily use of the school facilities and grounds lends itself to a host of engaging science and technology issues that introduce problem solving within a set of constraints such as time, cost, risk, and aesthetics. By exposing students to the ever-present relationship between the engineered world and their own lives through tasks, observations, and events of varying complexity, accomplished teachers provide students with firsthand experiences that encourage innovation, curiosity, and creativity. In this manner, students not only discover the ways in which technology influences their personal lives and the world around them but also experience how it does so and how they can put technology tools to good purpose. For these reasons, accomplished science teachers seek to take advantage of technology issues to advance students' understanding of science and to begin the journey toward literacy in technology.

Teachers lead discussions and set up opportunities for small group talks to help students digest new ideas and to identify useful strategies for enabling independent science thinking in the future. They present introductory or summative mini-lectures on essential science topics from time to time, and they do so judiciously.

Accomplished science teachers are immersed in their curriculum to the degree that when distractions and interruptions happen throughout the school year, teachers remain flexible and consistent. For example, when the daily schedule is adjusted to accommodate schoolwide testing, teachers easily adjust their lesson plans, maintain key curriculum objectives, and stay consistent in their implementation.

Teachers act as facilitators of students' intellectual explorations and initiatives and help guide them toward scientifically valid mental constructs about the natural and engineered worlds. In pursuit of this objective, teachers adjust their practice, as appropriate, to student performance and responses. They make midcourse corrections when an activity falters and improvise when an unanticipated learning opportunity presents itself. They willingly allow student thinking to drive the lesson but make sure the lesson adheres to both its conceptual framework and its key learning goals. As a result, students have a stake in what happens in science class, even though their every suggestion may not be pursued.

Meaningful Learning

Accomplished teachers put scientific information in the context of larger unifying concepts and organizing themes, such as cause and effect, structure and function, and patterns of change, that cut across disciplinary boundaries and encourage students to make connections between their previous understandings and everyday experiences and the scientific principles under consideration. Teachers further support the sense-making efforts of young adolescents by proceeding from the concrete to the abstract, by expanding from the local to the global, and by integrating science with the exploration of other disciplines as well as with technology-related issues.

Teachers translate difficult content into language that is meaningful to students.

When using analogies to present difficult science concepts, accomplished teachers make sure that students understand similarities and limitations, explaining not only where valid similarities exist but also where the analogy breaks down. For example, an accomplished teacher may explain the form and function of an animal cell by using the following analogy with a factory: The walls of the factory are like a cell membrane (raw materials are brought in and waste materials are discarded). However, the walls of the factory are static with permanent entrances and exits, whereas the cell membrane is fluid and dynamic, permeable across the entire membrane.

Interdisciplinary Approaches

Through instructional choices, accomplished teachers invite students to explore science relationships across the curriculum rather than adhere rigidly to disciplinary boundaries. Teachers understand that the deepening of students' knowledge of the world, language facility, understanding of technology, command of mathematics, and growth in scientific literacy are inextricably intertwined processes. They regularly engage students in looking at questions from a scientific point of view across every facet of the school curriculum.

Accomplished teachers understand that mathematics and science curricula are interconnected, and they find methods not only to instruct students on the scientific concepts of their curriculum but also to support the instruction of the mathematics curriculum. Science teachers have a working knowledge of the number system—including arithmetic operations, geometry, measurement, statistics, and probability—and they understand the relationship between graphs and symbolic representation. They help students learn mathematics in the context of their science explorations and use their mathematics reasoning skills to discern relationships in the natural and engineered worlds.

Accomplished teachers are aware that effective communication of scientific ideas is vital to students' learning and understanding of science. In relation to English language arts, teachers understand the connections between students' growing language proficiency and their ability to reason logically and communicate clearly. They regularly engage students in reading, writing, listening, speaking, and viewing while exploring the science curriculum. They advance students' understanding of the science curriculum through such means as increasing students' skills in reading scientific texts. They also help students communicate their understanding effectively in multiple ways. For example, they may ask students to develop a concept map on genetically altered food and write a persuasive essay supporting their position, or they may have students write a lab report accompanied by a graphic. They give students feedback on their communication skills. In pursuing these objectives with students, teachers model the use of Standard English in their own speaking and writing.

Accomplished science teachers find ways to place science in its context in the real world by exploring science concepts and their function in society. A way of integrating social studies into science could include, for example, a unit on forces shaping Colonial America in which students might study some or all of the following: the importance of tobacco to the economies of the early settlements, the principles of crop rotation and difficulties of pest control, the influence of this labor-intensive crop in concentrating the institution of slavery in the South, and the addictive properties of tobacco and the disastrous effect of smoking on human health.

Reflections on Standard VII:

Standard VIII: Science Inquiry

Accomplished science teachers involve students in the processes of inquiry that challenge students' thinking as they construct an understanding of nature and technology.

Science education seeks to help students acquire the cognitive operations, habits of mind, and attitudes that characterize the processes of scientific inquiry—that is, to have them learn through direct experience how scientists question, think, and reason.[7] Early Adolescence/Science teachers understand that this is a long-term goal and that, by applying their knowledge of the cognitive development of their students, they progress toward its realization along several important fronts. Specifically, accomplished teachers help young adolescents become more sophisticated, systematic, and independent in their investigations of natural and engineered phenomena; understand what makes a good science experiment; and notice and repair breakdowns in their reasoning, such as false analogies, sample bias, or the lack of a control. Teachers help students construct understanding from their experiences and connect what they do in science class to their everyday experiences. Accomplished teachers strive to make these experiences enjoyable so that students feel motivated to continue learning science.

The Process of Inquiry

People follow innumerable paths in seeking new knowledge about natural and human-made phenomena. Accomplished teachers understand that the inquiry process itself is not a uniform series of predetermined steps. Nevertheless, certain patterns of investigation are characteristic of effective inquiry.[8] Students learn to recognize problems, ask relevant questions, formulate working hypotheses, determine the best way to observe phenomena, handle data with accuracy, reach tentative conclusions consistent with what is known, and express themselves clearly about the significance of findings. The acquisition by students of cognitive processes such as these and the habits of mind and attitudes that underlie them is a fundamental component of the science curriculum.

Teachers know that fostering these complex mental capacities in young adolescents takes time. They recognize that students become adept at scientific thinking over time and that adolescents learn best by doing and then having adequate time to reflect on what they have done in order to reconcile their findings with their previous picture of the world.

Types of Inquiry

Accomplished teachers organize their classrooms around frequent, hands-on explorations of natural and engineered phenomena in which students assume age-appropriate active roles as investigators and sense makers. Teachers recognize that there are several different types of inquiry and understand how and when to best use them.

Science teachers may use a rational approach, which directs students to generalizations by the use of reason and entails the use of open-ended questions. They may

7. National Research Council. *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (Washington, D.C.: National Academy Press, 2000).

8. See also, for example, *National Science Education Standards.*

employ deductive inquiry activities, in which students work with concepts and general ideas in efforts to narrow down solutions to specific answers. For example, they may study parallel and series circuits and then applying this information to creating a circuit using a switch.

Teachers may use a discovery approach, in which students manipulate materials and data. Teachers can design guided discovery activities, which help students grasp certain scientific ideas by having them perform selected activities designed to answer a particular question. For example, when working with wires, bulbs, and batteries, the teacher would direct the students to construct a circuit in which one light bulb stays lit when a second one is unscrewed from its socket.

Accomplished teachers also understand the premise of open discovery. They provide materials and minimal (but important) direction for students to discover scientific concepts. For example, they may have students disassemble strands of lights to learn how the circuit works.

Teachers also understand the experimental approach, which is typically identified as "scientific inquiry," and in which the teacher and/or students select a problem to investigate, design a method for investigating it, conduct the experiment or investigation, and then analyze and report the results. For example, after the teacher presents the problem of providing electrical circuits for a model house, students design an electrical plan, develop the electrical circuits needed to light various rooms, analyze their plan, and present a report on their findings.

Although this listing of types of inquiry is not exhaustive, teachers who use inquiry involve students in constructing their understanding of phenomena, concepts, principles, experiences, and applications by thinking and writing about them, by conducting research, and by interacting with one another and with the teacher.

Fostering Science Inquiry

In choosing or designing learning opportunities, accomplished teachers keep a number of important criteria in mind. Recognizing that not all hands-on activities constitute true inquiry, they look for activities that are appropriate to the developmental level of their students; likely to raise interesting, worthwhile questions; relevant to the lives of all their students; and flexible, allowing active participation and student control over the manipulation of variables and the posing of questions while still reflecting content goals.

Teachers know that underpinning the processes of science are habits of mind and attitudes, such as objectivity, persistence, and collaboration, that both describe the ethos and represent the core values of the scientific community. (See Standard VI—*Learning Environment* for an expanded list.) Accomplished teachers incorporate these values in their classrooms so that students acquire a sense of how science communities function by being part of one.

Communicating Understanding

Accomplished teachers ensure that the hands-on activities they select challenge students intellectually and set the stage for increasingly sophisticated classroom discourse that leads to the clear communication of students' ideas. This focus on the interchange of ideas, whether through discussions or the sharing of written work, is vital, for through such discourse a classroom of individuals seeking knowledge is transformed into a community of learners seeking a consensus of understanding. Such classroom communities pursue the inquiry process purposefully. As individual students communicate their observations and ideas to their peers, they discover to what extent their perceptions are shared—

and if not, why not. In the course of this conversation, students refine and elaborate their personal understandings of the natural world while also developing a sense of the rules of evidence and modes of argument that govern the inquiry process. Ultimately, the accomplished teacher guides students to closure in their understanding of the important science topics they have explored through inquiry and helps them establish a variety of ways to communicate those understandings.

In facilitating classroom discussions or activities, teachers model good scientific discourse and ask thought-provoking questions. Such questions stimulate a rich interchange of ideas as teacher and students test one another's assumptions, premises, and conclusions. Teachers monitor students' direct involvement in classroom discourse. Accomplished teachers allow appropriate wait time after their own questions and after student responses to permit students time to think deeply. They value all contributions to a discussion, even as they coach students to probe constantly the reasons that lie behind a hypothesis and emphasize the need for credible evidence and consistency. They listen to students' ideas and make connections to other topics. They frequently use students' own words rather than the specialized vocabulary of a given field when talking about a science topic in order to show young adolescents that scientific knowledge strongly connects to their personal knowledge of the world. When necessary, however, they draw attention to the distinction between the colloquial use of a word (such as "food" or "energy") and its scientific usage. They know when and how not to say too much. They encourage student-to-student interaction in discussion. The tentative, hypothetical, exploratory language scientists themselves use often illuminates the discourse in their classrooms.

Teachers guide students in communicating their thoughts, ideas, and conclusions via oral, graphic, and written means. They help students distinguish among observation, results, and conclusions when writing up their experiments; represent results using tables, charts, graphs, and diagrams; and communicate scientific information clearly and accurately.

Promoting Growth in Inquiry

Accomplished teachers encourage the growth of students' understanding of the processes of scientific inquiry by offering students abundant opportunities to practice them and, when teachable moments present themselves, by demonstrating or directly teaching scientific principles. For example, teachers might take the opportunity to talk through a science question that comes up in the course of an activity, clarifying the thought processes and strategies that an expert in science uses when faced with a new challenge. They are mindful that the long-term goal of education is to cultivate lifelong learners. Accordingly, they take care to foster students' intellectual independence—at first modeling and demonstrating the thinking processes of a scientist for their student-apprentices but gradually stepping back to make way for increasingly self-directed student initiatives.

In pursuing an inquiry-based curriculum, teachers show themselves as intellectual risk takers. They willingly live with the sometimes unpredictable consequences of an activity-based 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 do not regard such experiences as failures, however, but rather as opportunities to think carefully about what has happened and learn from them. They understand and help students move through the emotional stages that accompany the

inquiry process. Teachers know that the conclusions students formulate are internalized and that understanding the processes of science implies experiencing all the sensations that scientists do, including confusion, frustration, excitement, and exhilaration.

Reflections on Standard VIII:

Standard IX: Contexts of Science

Accomplished science teachers create opportunities for students to explore science in a variety of contexts, including its history, its reciprocal relationship with technology, and its impact on society.

Science is a way of looking at the world and interpreting it in a thoughtful 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. In order for students to perceive science as alive with possibilities and not simply as a static body of knowledge, accomplished science teachers know that students must be exposed regularly to the contexts of science. Such contexts may include stories from the past about the struggles, setbacks, and triumphs of individuals and teams of investigators in their quest for deeper understanding of the natural world.

Human Contexts

Accomplished science teachers provide a complete picture of the human contexts of science. They emphasize the inquisitive nature of scientists, the manifestation of scientific investigation itself in leading to scientific discovery, and the role that a healthy sense of wonder plays in the lives of all people who value science. In broaching a topic, they acquaint students with stories of some of the people and major events that impelled or were affected by a discovery. On occasion they may ask students to try to solve the same challenge faced by a previous investigator. One of the best ways for students to learn about the actual practice of science is to encounter concrete examples that illustrate the reality of the practice. Such examples might show that science ordinarily grows by accretion through the contributions of many investigators operating within a stable paradigm, whether working alone or collaborating with others; that paradigm shifts or "revolutions" are often met with resistance within the scientific establishment; and that scientists are subject to the same kinds of weaknesses, temptations, and disagreements as people in other lines of work, but that the scientific community demands reproducible proof and eventually yields to logic based on this proof.

Historical Contexts

Accomplished teachers make sure that students develop a rich and diverse historical perspective on science because they realize that such knowledge forms a vital part of their shared cultural heritage. Certain episodes are so integral to the development of modern science that all students should be exposed to them, such as Galileo's insistence on experimentation to establish scientific proof and Marie Curie's insights into radioactivity. A historical perspective makes students aware of the impressive technological achievements of early Arabic, Chinese, Egyptian, Greek, Phoenician, and Polynesian cultures, to name a few, and of the substantial contributions of women and persons of color to science.

Historically, scientific advancements have resulted from collaboration among the disciplines of science, mathematics, and technology. Studying the history of science

tends to highlight the reciprocal relationship in the development of these three disciplines, each of which has an essential place in the education of the scientifically literate individual.

Science, Technology, and Society

The interdependent relationship among science, technology, and society must include an examination of the economic, cultural, and social changes precipitated by these forces. Accomplished teachers are aware of the close-knit origins of technology and science and make explicit the multiple connections between their coevolution over time and the course of civilization. Such teachers build on students' considerable familiarity with common examples of technology in modern society to explore both the promise and the perils of society's reliance on technology, such as examining how antibiotics have helped save lives and cure diseases, yet have also contributed through their overuse to increased resistance among some bacteria.

Research suggests that adolescents will engage in science learning when they see its connection with their daily lives. Accomplished teachers include a variety of activities focused on critical thinking about science, technology, and social issues as part of the curriculum because of the strong motivating powers of these issues. These activities might include conducting case studies of technology-precipitated changes, such as space travel; role playing a technology-related debate on a controversial issue, such as cloning; conducting issues investigations and action units on topics such as mountaintop removal or deforestation projects; and simulating consequences using a computer program, such as the nuclear fallout from an accident at a nuclear power plant. In various ways, accomplished teachers provide opportunities for students to explore science- and technology-related societal issues relevant to them and their community; to practice making responsible decisions that are based on information originating from multiple sources and perspectives on an issue; and to define actions toward resolution of an issue on the basis of informed decisions.

Reflections on Standard IX:

Standard X: Assessment

Accomplished science teachers employ a variety of assessment methods to obtain useful information about student learning and development, to guide instructional decisions, to report student progress, and to assist students in reflecting on their own learning.

Assessment—the process of using formal and informal methods of data gathering to determine students' growing scientific literacy—is a critical, ongoing element in the accomplished science teacher's pedagogy. Good assessment practices have the power to support deep student learning and breadth of application, just as ill-designed or haphazard ones can undermine instruction.[9] Accomplished science teachers view assessment as a strategic and integral part of their instruction that benefits both teacher and students.

Accomplished teachers have command of a wide range of assessment methods and strategies that align with the central goals of the science curriculum, and they select and tailor their assessment strategies to meet the diverse needs of students. They use their assessment practices to guide their instructional decisions, involve students in thinking about their own progress, and keep parents and other concerned adults well informed about students' work.

Assessment and Instruction

In the practice of accomplished teachers, assessment and the daily flow of instructional activity are difficult to separate or distinguish from one another. Assessment is a recursive process that occurs before, during, and after instruction, and accomplished science teachers know the appropriate skills and concepts to be assessed at different points in the instructional sequence.

Before instruction begins, teachers lay the foundation for all ongoing assessment strategies for any given unit of study by accessing prior knowledge, identifying misconceptions, and determining conceptions. They access prior knowledge to find out what students already know about a given topic, using techniques such as concept mapping or conducting a group dialogue. They identify the types of thinking processes that they plan for students to use and develop, such as questioning, hypothesizing, drawing conclusions, heuristic thinking, comprehending, analyzing, synthesizing, and evaluating, and they are able to choose appropriate assessment tools with which to evaluate those thinking processes.

During instruction as well as at its conclusion, accomplished teachers evaluate students' understanding and application of subject content and factual knowledge. Teachers observe class interactions, noting student contributions to small-group discussions, project designs, labs, or other problem-solving activities. They have procedures for credibly managing the task of thoughtful, systematic recording of their observations of student activities and performances. They draw on their knowledge of the subject and the results of formal and informal assessments to determine where misconceptions and gaps in students' knowledge may have occurred, and they reflect on these concerns and work with students to determine a course of action for improvement.

Accomplished teachers recognize the need for modifications in instruction and assessment to accommodate learning needs,

9 See for example, National Research Council. *Classroom Assessment and the National Science Education Standards.* J. Myron Atkin, Paul Black, Janet Voffey, Eds. (Washington, D.C.: National Academy of Science, 2003).

such as those documented on an individual student learning plan. They use assessments that take individual strengths and difficulties into account and focus both on individual growth and on the student's absolute level of performance. They recognize that although the assessment methods may have been modified, the expectation for student learning remains the same, and the outcome from the assessment should be consistent with that of the standards and goals set for instruction. They analyze assessment results in terms of student needs, teacher performance, and instructional sequence, and they make adjustments to instruction consistent with their findings.

Accomplished teachers are familiar with mandated achievement testing whether at the local, district, state, national, or international level. Recognizing the high-stakes nature of these tests, teachers actively seek information on the content standards and curriculum frameworks that underlie these tests, and they incorporate this information into their classroom activities to further students on a path to scientific literacy. Accomplished teachers are able to focus on inquiry-based learning as they prepare students for these tests. They know how to interpret and use large-scale testing data to improve instruction and student learning.

Assessment Methodologies

Accomplished science teachers assess students through a variety of techniques to meet the needs of students. They design, select, and understand the importance of measurement tools that are appropriate, fair, and accurate. Assessments devised by the accomplished science teacher probe students' depth of understanding and breadth of application, not just their ability to recall facts. Teachers use assessment methods that reveal the student's thinking pattern—when he or she used the right method to arrive at a wrong answer—and that they can use to determine the direction of future instruction. They develop methods for recording assessment over time while recognizing that time is a limited resource that needs to be used wisely and efficiently when assessing students.

Effective assessment methods fall into several categories from which teachers select the most productive method to evaluate student progress throughout the unit of study. Accomplished teachers know the difference between formative assessments and summative assessments, and they design their evaluation strategies accordingly. They also understand the importance of both formal and informal assessment methods and incorporate them appropriately into every unit of study. In addition, these teachers understand the need for assessments that are connected to real-world applications, such as performance-based assessments, which require students to demonstrate that they can perform a task.

Accomplished science teachers maintain a toolbox of assessment strategies from which they can match the most effective assessment to the instructional strategy of each moment in the unit of study. These strategies include observation, conversation, performances, written responses, and selected responses.[10] Assessments may take the form of questioning students for understanding, conducting portfolio reviews, evaluating science projects and lab reports, videotaping lab performances, audiotaping teacher-student interviews, keeping response journals and logs, writing checklists, administering selected-response pre- or post-tests, conducting small-group conferences, leading problem-solving games, performing computer-based simulations, and other techniques. Portfolios in particular can effectively gauge student progress over time, provided they are meaningful records of the natural course of a scientific inquiry. Assessments might focus

10. North Carolina Department of Public Instruction. *Classroom Assessment: Linking Instruction and Assessment* (Raleigh, N.C.: North Carolina Department of Public Instruction, 1999), 44.

on several discrete logical steps that students use to arrive at solutions, or they may involve work performed over days or even weeks.

Accomplished teachers identify effective methods of evaluating individual student work. Within a cooperative learning assignment, for example, students may be asked to evaluate their own work and their group members' contributions using a predesigned evaluation instrument. Teachers also evaluate students' ability to organize and archive their learning throughout a unit of study. This may be done by using laboratory notebooks in which students collect, organize, and analyze materials following teacher-specified criteria, then submit the notebooks as evidence of achievement.

Accomplished teachers may use technology to further assess student learning and classroom instruction. For example, through electronic simulations, teachers can evaluate students' problem-solving skills as well as determine whether a lesson's goals are achieved. Technological assessments can provide rapid comprehensive feedback, enabling teachers to monitor and adjust instruction in a responsive manner. Additional technological assessments can take the form of Web Quests, assistive technology, computer-based lab tools, and Web-based research projects.

Student Self-Assessment

Accomplished teachers involve students in assessing their own progress. They do so because they know that the ability to self-assess is an important element in fostering the growth of responsible, independent, lifelong learners. These teachers encourage students to set high goals for themselves and teach them how to evaluate their own progress toward these goals.

Accomplished teachers clearly communicate their expectations for student learning using exemplars and rubrics so that students can judge how well their work meets those expectations. Teachers develop students' abilities to think about what they know, how they know it, and the extent to which they demonstrate that knowledge.

Accomplished teachers provide multiple opportunities for students to assess and articulate the quality of their own work, such as projects and demonstrations, by using journals, portfolios, conferences, student-created rubrics/scoring guides, and other suitable means. For example, students might select which projects to include in their science portfolio and justify their choices with a written explanation. Students might work through a self-evaluation concerning their work on a given unit, or they might respond to a survey that probes their attitudes toward important learning goals in science. Any one of these activities might later become part of the science portfolio and the text for a student-teacher conference. Accomplished teachers also engage students in peer review, which can provide fresh perspectives on students' own work.

Feedback

A key purpose of assessment is to help students monitor and reflect on their progress and learning in order to initiate steps for improvement. Accomplished teachers use constructive feedback to increase student learning or to correct misconceptions. Constructive feedback should be specific and should be used to improve student performance, promote growth, and increase a student's self-worth.

Accomplished teachers prepare evaluations of student progress that clearly communicate to students, parents, and administrators the kind and quality of gains in science literacy that students have been making and, when appropriate, the need for improvement.

Teachers provide parents with regular reports (e.g., phone calls, progress reports, e-mail notices) and with meaningful information (e.g., examples of the kind of work their child is capable of doing in science class) contextualized by student performance standards. (See Standard XI—*Family and Community Outreach.*)

Teachers also share with colleagues and administrators their thoughts on the success of the science program as a whole and how it might be improved. (See Standard XII—*Professional Collaboration and Leadership.*) In these ways, the accomplished science teacher uses feedback as a tool for improving both student learning and the curriculum.

Reflections on Standard X:

Supporting Teaching and Student Learning

The final section of *Early Adolescence/Science Standards* treats those aspects of practice that guide and continually improve teaching. These include techniques for recruiting home and community support for the science program (Standard XI—*Family and Community Outreach*); for contributing to the growth of the individuals and institutions in the larger professional community (Standard XII—*Professional Collaboration and Leadership*); and for self-evaluation and analysis (Standard XIII—*Reflective Practice*). This set of standards pertains mainly to actions teachers take outside the classroom to support improvements in their teaching and student performance.

Standard XI: Family and Community Outreach

Accomplished science teachers proactively work with families and communities to serve the interests of students.

Accomplished teachers know that families and communities are important partners in educating children, and they effectively cultivate these partnerships to enhance student learning. Families and communities are valuable resources for providing information about students and enhancing their science learning.

Family Collaborations

Accomplished teachers know that the expectations and actions of families directly affect the learning success of students. They respect the role of families as students' first teachers and acknowledge the high aspirations that most families hold for their children's success. Early in the school year, these teachers take steps to solicit support for the science program from parents and other adult caregivers. They are receptive and welcoming in their attitude; they establish two-way communication with families, seeking information from them about their children's strengths, science interests, preferences, aspirations, and home life. They provide information about the school science program's content, routine, and goals. They suggest actions families can take to help their children's science literacy growth, such as providing a quiet place and set time for doing homework, encouraging thinking and reasoning about everyday phenomena, and expecting their children to do well in science and communicating that expectation.

These teachers see parents and adult caregivers as allies. They communicate regularly with families about the school science program through newsletters or other media. They invite parents to take part in the science program, for example, as collaborators in planning the school science fair. In their communications with parents, teachers may mention research regarding key nurturing tips that families might find useful—such as the importance of encouraging daughters in science-related endeavors and the importance of understanding how effort, not just ability, is a key to success in science. Accomplished teachers communicate regularly with families about their children's progress in science and

respond thoughtfully to their concerns. They help families avoid an overreliance on large-scale test scores as the sole indicators of achievement by providing concrete examples of what their children can actually do in science. (See Standard X—*Assessment.*) Science class eventually brings students into contact with important topics that some portions of the population may find objectionable, such as evolution or the use of fetal tissue in medical research. Accomplished teachers know how to handle these concerns, keep open lines of communication with families, and respect families' private beliefs. In teaching adolescents about the structure and functions of the human body, for example, an accomplished teacher might inform parents about the unit, invite them to share their perspectives, and use their input to influence the program's delivery.

Teachers communicate to families the importance of the family's role in students' science learning. They make clear that family members do not need advanced degrees to help adolescents learn science; what families really need is to be willing to make an effort, to share in their children's curiosity about their everyday world, and to watch and learn along with them. From time to time, teachers may send home a science activity kit or design an intriguing brainteaser with an eye toward involving the whole family in thinking up solutions.

Teachers create opportunities for family members to participate at school as guest speakers or volunteers in the classroom. For example, during a plant biology lesson, a parent with horticultural experience may be invited to share that expertise in the class. Teachers may organize special events that will involve the entire family, such as family science nights at the school, or may invite them on field trips.

Accomplished teachers recognize that families have experiences and insights that, when tapped, can enrich the quality of education for students. They elicit parents' ideas about their children's interests and about ways to motivate them. They respond thoughtfully and thoroughly to parents' concerns. In so doing, teachers interact as effectively as possible with families; such partnerships cultivate interests that extend beyond the school setting.

Aware that complexities of family structure frequently affect academic performance, accomplished teachers familiarize themselves with the family situations of their students as conditions warrant. Involvement with parents helps teachers learn about a family's background and culture, creating a window through which they can gain insight into parents' expectations and aspirations for their children. They treat families with sensitivity, respect, and understanding, realizing that parents' prior experiences with school often frame their expectations and attitudes. These teachers welcome the keen observations and reports that parents often provide about their children. Such understanding of children's lives outside of school and of their access to home resources is often important in tailoring the curriculum and instruction within the school.

Community Collaboration

Accomplished teachers make optimum use of the people, institutions, and other resources available in the community to enliven students' understanding of science. (See Standard III—*Instructional Resources.*) For instance, they may form partnerships with the local police and fire departments, farms, senior citizens groups, chambers of commerce, corporations, or small businesses to bring the world of science and technology, past and present, into the classroom. Accomplished teachers typically go beyond the classroom—to visit neighboring science research centers, aquariums, planetariums, botanical gardens, parks, museums, zoos, or other areas of interest—to extend students'

learning. They know that people in the community may provide grants or other donations to assist with implementing the curriculum, as well as providing instructional resources. Teachers may also find ways to positively involve the media in events that feature the school and the community. The accomplished teacher strategically chooses from this wide array of resources to create opportunities to enhance the curriculum.

Teachers are conscious of the obligations of membership in a community. Through their example and leadership, they foster in students a sense of community responsibility and citizenship. They often involve students in science-related activities that benefit the community, such as supporting the local Red Cross blood drive, doing volunteer work removing nonnative species, or recapturing green space. Such involvement shows the community positive elements of the students and the school while showing the importance of community involvement and by providing real-world connections that are essential for student learning.

Reflections on Standard XI:

Standard XII: Professional Collaboration and Leadership

Accomplished science teachers collaborate with colleagues and take leadership roles in their own educational community, as well as the larger community, to advance student learning.

Accomplished science teachers are active members of learning communities. They understand that they need not work in isolation. Accordingly, they contribute to the improvement of the practice of their colleagues as well as the instructional program of the school and the larger professional community. Collaboration among professional stakeholders is highly valued and leads to opportunities to advance student learning and to take a leadership role in improving the profession.

Collaboration

Accomplished teachers strengthen the school as a learning community in many ways. They are team players, committed to supporting the school's overall mission. They serve as models for other teachers in the school through their daily contact with students, the lessons they develop and implement, their contributions to the operations of the school, and their commitment to the advancement of their profession. They participate in the solution of schoolwide problems and policy issues, collaborating with administrators and other professionals to consistently support schoolwide initiatives. They willingly develop and analyze curricular materials for their department, and they are active participants in department meetings and other department functions.

Accomplished science teachers collaborate with support personnel, such as school counselors, learning specialists, resource teachers, team members, and parents, to ensure that students with special needs or special circumstances have positive science learning experiences. They advocate for students and their science learning with colleagues and parents during individual educational plan meetings, team meetings, disciplinary hearings, and other arenas where their input about student performance is needed.

Accomplished science teachers act as science resources for colleagues in other disciplines and collaborate to build meaningful connections across content disciplines. They actively seek opportunities to integrate other subjects into their instruction and to be involved in interdisciplinary activities. For example, a science teacher and an English language arts teacher may collaborate on an advertising unit in which students conduct research, write copy, and videotape an advertisement for a commercially available product.

Accomplished science teachers act as science resources for colleagues in their own discipline and collaborate to ensure that the scope and sequence of their district curriculum is rich and sequential. They engage in meaningful dialogue with other science teachers to strengthen the science experience for students at all levels. They serve as

mentors or peer coaches to novice teachers in their discipline and to other professionals who may have limited science background or who are searching for knowledge to enrich their own delivery of science in their practice.

Teachers may advance the knowledge and practice of colleagues, at the school and beyond, in several other ways as well. They may collaborate with university colleagues in advancing the state of science instruction. They may design and carry out professional development workshops in science. They may collaborate with local higher education colleagues to share their expertise in science teaching by mentoring pre-service teachers. They may observe and make suggestions on the instructional approach of colleagues when asked and, in turn, welcome their peers into their classrooms and laboratories.

Accomplished science teachers have a positive and professional attitude toward colleagues. They eagerly learn from them and share instructional activities and effective strategies. They are not deflected from their commitment to the progress of the science program by the unwillingness of some colleagues to join in their efforts, even when met by outright criticism. Rather, they respect the need for each science teacher to construct a unique vision of quality practice and to adopt only those changes in pedagogy that make sense to the individual. Consequently, teachers stand ready to assist colleagues when collegial interaction is welcome, and they influence by example when it is not.

Professional Contributions

Accomplished science teachers lead by example and take active roles in promoting science education within their schools, districts, regions, or beyond. They are mindful of their responsibility not only to further their profession but also to further student learning.

Accomplished science teachers may organize informal study groups to discuss important topics or research papers. They may put on demonstrations of successful practices, organize workshops or in-service days, or contribute to professional and scholarly publications. They may join, be active in, and contribute to professional organizations. They may serve on local, regional, state, or national education task forces, and they may use their knowledge of science and its effects on society to benefit the communities in which they teach and live.

Reflections on Standard XII:

Standard XIII: Reflective Practice

Accomplished science teachers continually analyze, evaluate, and strengthen their practice in order to improve the quality of their students' learning experiences.

Accomplished science teachers are reflective practitioners who constantly strive to become masters of their profession by analyzing, evaluating, and strengthening their practice in order to improve the quality of their students' learning experiences. They understand and use a conceptual framework, such as their philosophy of education or action research, to reflect on their practice. As they reflect on their practice and assess their effectiveness, they adapt, revise, and strengthen their teaching to make learning more meaningful to early adolescents. They recognize that the demands of accomplished science teaching change over time—indeed, change with each class and each student. They view each year as another opportunity to improve the quality of their own teaching practice and to enhance the knowledge and stature of their profession.

Refining Practice

The process of teaching science is a contextual one in which teachers are constantly making decisions as they react to and interact with students and their educational environment. Accomplished teachers possess a spirit of inquiry and embrace reflective conversation as they attempt to understand their students' backgrounds, cultures, knowledge, and understandings about science in order to better serve their students.

Teachers have a vision for their students, the dynamics of their classroom, their own teaching role, and the future of the profession. They are aware of their personal strengths and needs for improvement. They can describe how their particular cultural background, biases, values, and life experiences might limit or enhance their teaching effectiveness, and they endeavor constantly to broaden their perspectives. (See Standard IV—*Diversity, Equity, and Fairness.*)

Reflective teachers' actions are a result of careful thought and decision making rather than an applied set of routine skills. This careful thought includes technical knowledge, past experience, and consideration of the constraints of the system within which the teacher works. Teachers seek understanding of the purposes and consequences of their actions. They continually analyze their practice, asking themselves and others such questions as "What went well?" and "How could I do better?" When things go well, accomplished teachers think about why classes succeeded and how to adapt the lessons they learned to other classes. When things go poorly, they reflect on how to avoid such problems in the future. This analysis is sometimes accomplished through journal writing, reflective portfolios, and other means of introspection. Accomplished teachers have a variety of self-assessment and problem-solving strategies.

Reflective science teachers use the knowledge of their practice to seek opportunities for professional growth. They constantly strive to be informed, challenged, and motivated to do their best for their students and the profession. They participate in a wide range of reflective practices that reinforce

their creativity, innovation, personal growth, and professionalism. They exemplify the highest ethical and moral ideals of the craft and embrace professional standards in assessing their practice. Ultimately, this habit of self-reflection contributes to their depth of knowledge and skill and validates their practice.

Resources for Reflection

Accomplished teachers avail themselves of many resources in analyzing the appropriateness and effectiveness of their teaching. They seek feedback from students, colleagues, administrators, and parents. Fellow teachers, in particular, are a rich source of perspective and insight. (See Standard XII—*Professional Collaboration and Leadership.*) Reflective teachers keep themselves up-to-date on significant research findings in science, which they assimilate with the open-mindedness and skepticism of a scientist. Therefore, they consider themselves to be working on the front line of educational research. They have positions on the major controversies in the field. They use district curriculum guides as well as state and national science frameworks; read professional publications; participate in professional organizations; and take advantage of professional development opportunities. They consider new pedagogical ideas in the teaching of science and make sound judgments regarding the applicability of these ideas to their own teaching. They can speak compellingly about why they make certain pedagogical decisions. Teachers constantly add to their classroom repertoire of effective demonstrations, explanatory analogies, and learning experiences that intrigue students and stimulate their interest and thinking.

Personal Reflection

Accomplished science teachers actively seek opportunities for self-renewal and self-improvement through reflection. They recognize and affirm the value of a balanced, full, and rewarding life. They thoughtfully maintain a strong personal identity while carefully evaluating time commitments and the quality of relationships developed and advanced outside their teaching responsibilities. They practice and improve their teaching concurrently with the other meaningful aspects of their lives.

Reflections on Standard XIII:

Epilogue

The 13 standards in this report represent a professional consensus on the characteristics of accomplished practice and provide a profile of the accomplished Early Adolescence/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, *Early Adolescence/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.

Early Adolescence/Science Standards Committee
Developers of First Edition

Christina A. Castillo-Comer—Chair
Mentor Teacher
San Antonio Urban Systemic Initiative
San Antonio, Texas

Patricia Heller—Vice Chair
Assistant Professor of Science Education
University of Minnesota
Minneapolis, Minnesota

Charles W. Anderson
Associate Professor of Science Education
Michigan State University
East Lansing, Michigan

Mary M. Atwater
Assistant Professor
Department of Science Education
University of Georgia
Athens, Georgia

C. James Bailie
Biology Teacher
Chippewa Falls Middle School
Chippewa Falls, Wisconsin

Melanie Barron
Coordinator of Science
Cambridge Public Schools
Cambridge Rindge & Latin School
Cambridge, Massachusetts

Michael T. Burton
Earth Science Teacher
Agassiz Junior High School
Fargo, North Dakota

Angelo Collins
Associate Professor
Peabody School of Education
Vanderbilt University
Nashville, Tennessee

Patricia Ann Kenzig
Science Teacher
Beaumont School
Cleveland Heights, Ohio

Douglas Leonard
Life Science Teacher
Brynedale Junior High School
Toledo, Ohio

Gail M. Morse
Physical Science Teacher
Zebulon Middle School
Zebulon, North Carolina

Peter A. Rubba
Professor of Science Education and
Science (Technology Society Education)
Pennsylvania State University
University Park, Pennsylvania

All job titles reflect those held by committee members at the time the first edition of *Early Adolescence/Science Standards* was adopted by the NBPTS Board of Directors.

Early Adolescence/Science Standards Committee
Developers of Second Edition

Catherine Anderson, NBCT—Chair
Physical Science Teacher
DeLong Middle School
Eau Claire, Wisconsin

Wetonah Parker—Vice Chair
Associate Professor
School of Education
Meredith College
Raleigh, North Carolina

Shelley Canright
Educational Technology Program Officer
National Aeronautics and Space Administration
Washington, D.C.

Caleb Cheung, NBCT
Science Teacher
Carter Middle School
Oakland, California

Joe Evans
Senior Vice President for Academic Affairs
Glenville State College
Glenville, West Virginia

Kevin Finson
Professor and Chairperson
Department of Teacher Education
College of Education and Health Sciences
Bradley University
Peoria, Illinois

Georgina Koch-Hidalgo, NBCT
Science Teacher
Ammons Middle School
Miami, Florida

Dan Monahan, NBCT
Mathematics and Science Teacher
Cambridgeport School
Cambridge, Massachusetts

Barbara Pietrucha
Earth Science/Environmental Science Teacher
Neptune Township Middle School
Neptune, New Jersey

Ron Reihl
Science Teacher
Tanana Middle School
Fairbanks, Alaska

Mary E. Staten, NBCT
Science Curriculum Specialist
Milwaukee Public Schools
Milwaukee, Wisconsin

Wayne Worthley, NBCT
Science Instructor
Redland Middle School
Homestead, Florida

Emily Young
Science Teacher
Louisiana State University Laboratory School
Baton Rouge, Louisiana

Acknowledgments

The National Board for Professional Teaching Standards' *Early Adolescence/Science Standards,* reflects more than a decade of dialogue about accomplished teaching in Early Adolescence/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. *Early Adolescence/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 *Early Adolescence/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 Christina Castillo-Comer and Vice Chair Patricia Heller 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 Early Adolescence/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 Early Adolescence/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 Catherine Anderson, NBCT; Vice Chair Wetonah Parker; and Facilitator Connie Bernash, NBCT, for their invaluable leadership in making the second edition a reality. In addition, 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 Kathleen Ruddy and Al Byers for serving as liaisons from the National Science Teachers Association.

The work of the Early Adolescence/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 Soto, NBCT, 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.

Acknowledgments

Many staff members and consultants to NBPTS deserve thanks for helping to make the publication of *Early Adolescence/Science Standards* possible. As staff liaison to the standards committee, former Manager of Certification Standards Michael Knab worked directly with the committee, making suggestions and guiding the entire development process. Writing credits go to Kim Worth, NBCT, who turned the ideas from the committee's rich conversations into clear and cogent prose. Thanks also go to the collaborative efforts of Teacher-in-Residence Mary Lease, NBCT; Teacher-in-Residence Maria Telesca, NBCT; Administrative Assistant Glowena Harrison; and Consultant Angela Duperrouzel, who skillfully supported the work of the standards committee in ways too numerous to mention.

In presenting these standards for accomplished Early Adolescence/Science teachers, 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.*

1525 Wilson Boulevard / Suite 500 / Arlington, VA 22209 / 703-465-2700