

Science Standards

Third Edition

for teachers of students ages 11–18+

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*National Board Certification
Promotes Better Teaching,
Better Learning, Better Schools*

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Preface

About the National Board for Professional Teaching Standards

The National Board for Professional Teaching Standards (National Board) is a not-for-profit professional organization, created and governed by practicing teachers and their advocates. The founding mission of the National Board 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 into American education and to capitalize on the expertise of National Board Certified Teachers.

Recognized as the “gold standard” in teacher certification, the National Board believes higher standards for teachers means better learning for students.

Founded in 1987, the National Board began by engaging teachers in the development of standards for accomplished teaching and in the building of an assessment—National Board Certification—that validly and reliably identifies when a teacher meets those standards. Today, there are 25 certificate areas that span 16 content areas and four student developmental levels. The essence of the National Board’s vision of accomplished teaching is captured in the enduring document *What Teachers Should Know and Be Able to Do*, at the heart of which are the Five Core Propositions:

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.

The National Board believes that board certification should become the norm, not the exception, and should be fully integrated into the fabric of the teaching profession. In other professions, such as medicine, engineering, and architecture, board certification has helped to create a culture of accomplished practice and is a major reason why those professions are held in such high regard by the public. Those professions did what teaching must now do: strengthen the coherent pipeline of preparation that begins in pre-service and continues through board certification and beyond, with each step engineered to help teachers develop toward accomplished. More than 110,000 teachers had achieved board certification by 2014, a number which represents the largest group of identified teaching experts in the country. Given the size of the teaching workforce, however, this sizable number represents fewer than 3 percent of teachers.

For most children that means they go through their entire schooling without being taught by a board-certified teacher. Each teacher who pursues board certification helps to close this gap, strengthening the profession and the quality of teaching and learning. In a world where board certification is the standard that all teachers aspire to and most achieve, students experience accomplished teaching throughout their schooling, unleashing their potential.

About the Standards

Every child deserves an accomplished teacher—one who is qualified to equip students with the skills to succeed in a global community. The core mission of the National Board for Professional Teaching Standards is to create field-specific standards for accomplished teaching that are grounded in the Five Core Propositions and that articulate the actions that accomplished teachers employ to advance student learning. Each standards document represents a professional consensus on the attributes of practice that distinguish accomplished teaching in that field. Many school systems use the standards as the basis for ongoing professional development, and many colleges and universities incorporate the standards into their undergraduate and graduate teacher education programs.

Standards are developed and revised by a committee of 12–15 members who are representative of accomplished professionals in their field. A majority of standards committee members are practicing Board certified teachers. Other committee members are experts in academic content and child development, including teacher educators, researchers, and other professionals in the relevant field. Standards are disseminated widely for public comment and subsequently revised as necessary before adoption by the National Board's Board of Directors.

Throughout the development of both the standards and the certification process, the National Board 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; and establishes procedures to detect and eliminate instances of external and internal bias.

National Board Standards and certifications are defined by the developmental level of the students and by the subject or subjects being taught. Teachers select the subject area that makes up the substantive focus of their teaching. They may choose Generalist certificates if they do not focus on one particular subject area in their practice. The four overlapping student developmental levels (listed below) indicate the age of the majority of their students.

- Early Childhood (EC)—ages 3–8
- Middle Childhood (MC)—ages 7–12
- Early Adolescence (EA)—ages 11–15
- Adolescence and Young Adulthood (AYA)—ages 14–18+

About Certification

National Board Certification® is a voluntary, standards-based process designed for teachers to transform the Five Core Propositions into practice. In order to be eligible for certification a teacher must

- Hold a baccalaureate degree from an accredited institution¹;
- Have a minimum of three years' teaching experience at the early childhood, elementary, middle school, or high school level; and
- Where it is required, hold a state teaching license.

The assessments, aligned with the Five Core Propositions and the standards, are designed so that teachers demonstrate their practice by providing evidence of what they know and do. The evidence-based assessment honors the complexities and demands of teaching.

In 2014, the National Board initiated revision of the assessment to make the process more flexible, affordable, and efficient for teachers. In all certificate areas, candidates for National Board Certification are now required to complete four components: three portfolio entries, which are submitted online, and a computer-based assessment, which is administered at a testing center. Teachers develop portfolio entries that require analysis of their practice as it relates to student learning and to being a reflective, effective practitioner. Designed to capture what a teacher knows and is able to do in real time and in real-life settings, the portfolio consists of description, analysis, and reflection focused on student learning that is captured on video and in student work samples. The process requires teachers to reflect on the underlying assumptions of their practice and the impacts of that practice on student learning.

Teachers also demonstrate content knowledge by responding to open-ended and multiple choice questions delivered at a secure testing site. The assessment center component complements the portfolio, validates that the knowledge and skills exhibited in the portfolio are accurate reflections of what a candidate knows, and provides candidates with opportunities to demonstrate knowledge and skills not sampled in the portfolio.

Assessments are based on the standards and are developed for every certificate area by educators who specialize in the same content and student developmental level as the candidates. Educators who are themselves practitioners in the certificate area score the submitted portfolio entries. They must successfully complete intensive training and qualify for scoring on the basis of their understanding of National Board Standards and scoring guidelines.

¹ Candidates registering for the Career and Technical Education certificate are required to hold a bachelor's degree only if their state required one for their current license.

Foundation of National Board Certification for Teachers

Five Core Propositions

The National Board framework for accomplished teaching was established in its 1989 publication, *What Teachers Should Know and Be Able to Do*. The Five Core Propositions serve as the foundation for all National Board standards and assessments, defining the level of knowledge, skills, abilities, and commitments that accomplished teachers demonstrate. Teachers embody all Five Core Propositions in their practices, drawing on various combinations of these skills, applications, and dispositions to promote student learning.

1. Teachers are committed to students and their learning.

Accomplished teachers base their practice on the fundamental belief that all students can learn and meet high expectations. They treat students equitably, recognizing the individual differences that distinguish one student from another and taking account of these differences in their practice. They adjust their practice based on observation and understanding of their students' interests, abilities, skills, knowledge, language, family circumstances, and peer relationships. They view students' varied backgrounds as diversity that enriches the learning environment for every student.

Accomplished teachers understand how students develop and learn. They consult and incorporate a variety of learning and development theories into their practice, while remaining attuned to their students' individual contexts, cultures, abilities, and circumstances. They are committed to students' cognitive development as well as to students' ownership of their learning. Equally important, they foster students' self-esteem, motivation, character, perseverance, civic responsibility, intellectual risk taking, and respect for others.

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 subject is created, organized, linked to other disciplines, and applied to real-world settings. While maintaining the integrity of disciplinary methods, content, and structures of organization, accomplished teachers develop the critical and analytical capacities of their students so they can think for themselves.

Accomplished teachers command specialized knowledge of how to convey and reveal subject matter to students. They are aware of the preconceptions and background knowledge that students typically bring to each subject and draw upon pedagogical and subject matter understandings to anticipate challenges,

modify their practice, and respond to students' needs. They also demonstrate a commitment towards learning about new strategies, instructional resources, and technology that can be of assistance. Their instructional repertoire and professional judgment allow them to generate multiple paths to knowledge in the subjects they teach, and they are adept at teaching students how to pose and solve their own problems so they can continue exploring and advancing their understanding.

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

Accomplished teachers view themselves as facilitators of student learning within dynamic instructional settings. They create, enrich, maintain, and alter learning environments while establishing effective ways to monitor and manage those environments and the student learning that occurs within them. They possess a comprehensive knowledge of instructional methods, know when each is appropriate, and can implement them as needed. They use instructional time constructively and efficiently, customizing physical layout, resources, and instructional methods. They enlist the knowledge and support of a wide range of stakeholders to provide their students with enriched opportunities to learn. They understand the strengths and weaknesses of pedagogical approaches they may take, as well as the suitability of these approaches for particular students.

Accomplished teachers know how to engage students in varied settings and group configurations. They create positive and safe learning environments that guide student behavior and support learning, allowing the schools' goals for students to be met. They are adept at setting norms for social interaction among students and between students and teachers. They understand how to motivate students and value student engagement, supporting them as they face and learn from challenges.

Accomplished teachers assess the progress of individual students as well as that of the class as a whole. They apply their knowledge of assessment to employ multiple methods for measuring student growth and understanding. They use the information they gather from monitoring student learning to inform their practice, and they provide constructive feedback to students and families. They collaborate with students throughout the learning process and help students engage in self-assessment.

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

Accomplished teachers possess a professional obligation to become perpetual students of their craft. Committed to reflective learning, they are models of educated persons. They exemplify the virtues they seek to inspire in students—curiosity, honesty, fairness, respect for diversity and appreciation of cultural differences—and the capacities that are prerequisites for intellectual growth: the ability to reason and take multiple perspectives, to be creative and take risks, and to adopt an experimental and problem-solving orientation.

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 not only grounded in established theories, but also in reason born of experience. They engage in lifelong learning, which they seek to encourage in their students.

Accomplished teachers seek opportunities to cultivate their learning. Striving to strengthen their teaching and positively impact student learning, teachers use feedback and research to critically examine

their practice, seek to 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.

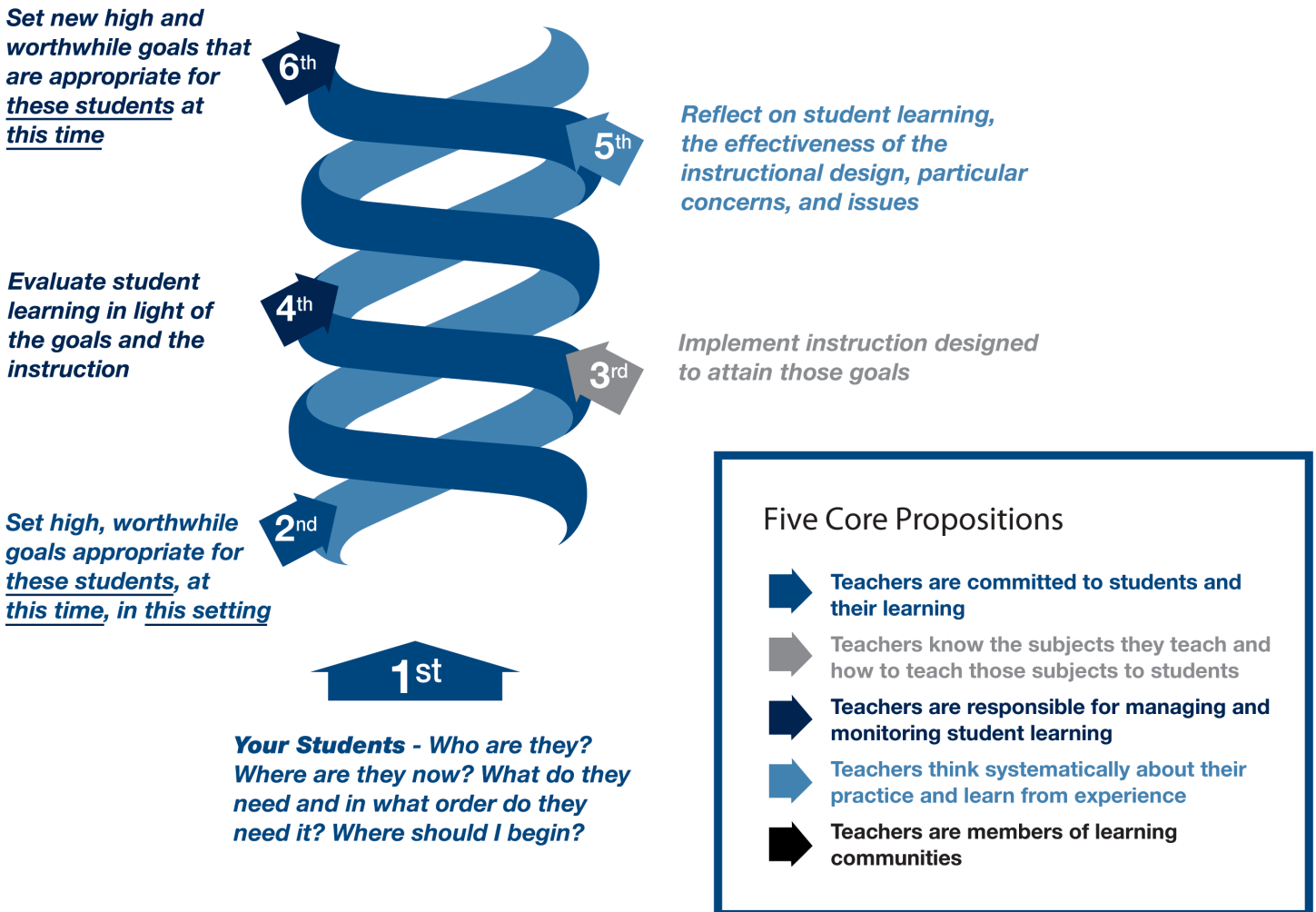
Accomplished teachers participate actively in their learning communities to promote progress and achievement. They contribute to the effectiveness of the school by working collaboratively with other professionals on policy decisions, curriculum development, professional learning, school instructional programs, and other functions that are fundamental to the development of highly productive learning communities. They work collaboratively and creatively with families and the community, engaging them productively in the work of the school and cultivating students' connections with the opportunities, resources, and diversity they afford.

Accomplished teachers can evaluate school progress and the allocation of school resources in light of their understanding of state and local educational objectives and their knowledge of student needs. They are knowledgeable about and can advocate for specialized school and community resources that can be engaged for their students' benefit, and are skilled at employing such resources as needed.

Architecture of Accomplished Teaching

The Architecture of Accomplished Teaching provides a view of how the use of the Five Core Propositions and the standards that are developed from them result in student learning. As depicted in the Architecture of Accomplished Teaching illustration, shown below, one strand represents teaching practice as grounded in the Five Core Propositions, while the other strand represents the teacher’s impact on students and their learning.

The Architecture of Accomplished Teaching: *What is underneath the surface?*



The National Board program certifies accomplished teachers who positively influence student learning through effective teaching practice. The process includes the core propositions for all teachers, a common set of accomplished teaching standards specific to the content field and students’ developmental levels, and a set of evidence-based assessments specific to the field that certify what accomplished teachers know and do.

Standards

Introduction

These standards were written by practitioners in the field of science education in order to clearly define the knowledge and skills possessed by accomplished science teachers. We, the members of the Science Standards Committee, combined the science standards for early adolescence and the standards for adolescence through young adulthood into a single, comprehensive third edition based on the understanding that teachers across these developmental ranges engage in common practices. We also understand that science standards for student learning are currently undergoing significant changes. An awareness is embedded throughout our document of the likely impacts that the Framework for K–12 Science Education and the Next Generation Science Standards will have on science teaching and learning in the coming years. However, the group’s thinking was not constrained by any one set of documents. Rather, we used our knowledge of all the forces shaping the classroom and our own wealth of experience to deliberate on, refine, and express a vision of what accomplished teachers understand, know, and do.

The Science Standards Committee included high school and middle school science teachers from rural, urban, and suburban school districts around the country; teacher educators; and curriculum specialists. Most of us developed a passion for science in childhood. Whether running through the woods during the summer, watching blood flow through the tail of a living and unharmed fish, breaking open rocks to reveal their insides, watching eggs hatch, or spending an entire day running between a creek and a microscope, we all had experiences in which we were awestruck by natural phenomena. In addition, all of us were inspired by the contagious enthusiasm of our own teachers. All of us are united by the belief that it is important for human beings to learn the nature of science and the principles of scientific inquiry, that all students are capable of learning science, and that it is our responsibility to promote science learning at the highest levels.

Science Standards, Third Edition, provides a clear, comprehensive, and nuanced vision of what it means to be an accomplished science teacher. Abundant creativity, intense curiosity, and rigorous analytical ability sustain practitioners in this discipline. We know that those of you who are reading this document share our enthusiasm for science and our high standards for science education, and we salute you as you move forward in your quest to become National Board Certified Teachers.

The Nature and Culture of Science

Science is a rigorous way to make sense of natural phenomena. Scientific knowledge is generated in many ways, but science rests upon certain core principles, including a reliance upon empirical evidence and the understanding that science takes place within a cultural context. Science is rooted in deep, broad content knowledge and in mastery of the techniques and purposes of scientific inquiry. Scientists are both disciplined and creative as they seek to expand the boundaries of knowledge.

Science is a culture with its own language, traditions, and values (such as valuing knowledge derived from empirical means over that formed from hunches, unsubstantiated stories, or pure conjecture). Accomplished teachers not only understand the culture of science, but also comprehend how to help students negotiate their entrance into the culture. Teachers give students the means to be productive, participating members of the scientific community.

Science and Students

Science teachers capitalize on the fact that students are naturally inquisitive and build on that curiosity. To learn science, most students require both explicit instruction and hands-on investigation. All students are capable of learning science, but they do not all learn science in the same way. Students of accomplished teachers understand the culture of science, become active members of scientific communities, formulate and investigate meaningful scientific questions, and gradually develop more sophisticated scientific understandings. Students learn to appreciate both the open-ended nature of science and its rigor. They take ownership of their science education.

Students learn science best when they have a rich and safe learning environment, high-quality (but not necessarily expensive) resources, and high standards. Science teachers need to modify instruction in response to students' diverse gifts and needs. Teachers need to know, and to help students understand, the many ways science impacts daily life and the ways students can apply scientific knowledge—whether in science professions or other fields. Well-designed and carefully interpreted educational assessments can provide teachers with valuable insights into students' scientific backgrounds and their progress toward clear goals. Fairness and equity are essential hallmarks of student-centered science education.

Science learning flows from scientific literacy and from general literacy. Science education must build carefully upon previous understandings. Students learn best through an interdisciplinary approach that explores the connections among different branches of science and between science and other fields such as math, technology and engineering, English language arts, and the social sciences.

Because science learning is connected to students' cultural backgrounds, science education must be fine-tuned to students' geographical, ethnic, economic, and personal characteristics. However, despite individual differences, all students are capable of conducting sophisticated scientific inquiry, both in the classroom and in collaboration with partners such as university researchers and government agencies.

The Changing Nature of Science and Science Education

An essential aspect of science is that it is always changing. Accomplished teachers keep up with relevant and important changes in scientific knowledge and convey appropriate information to their students. Approaches to science education are always developing as well. For this reason, *Science Standards, Third Edition*, discusses how teachers respond to changes in the landscape of science and the ways it can be taught.

Technology has had, and continues to have, a profound impact upon science. Science creates new technologies; innovative uses of advanced technologies assist in new scientific understandings; and the fields of science and technology and engineering are intertwined in an upward spiral of new knowledge and new applications.

Understanding the relationship between culture and science is increasingly important. Since it is a human endeavor, science can be viewed through historical, biographical, and ethical lenses. Technology is accelerating the ease and the pace at which scientific advances are being made and disseminated through global connections. Science educators have a greater appreciation now than in the past for the importance of community partnerships, student-centered inquiry, sustained professional learning, the ethical dimensions of science, scientific literacy, differentiated instruction, and the importance of addressing the whole student. Today there is a greater awareness of the value of scientific collaboration, within both the classroom and the world of professional scientists, and a focus on the fact that scientific discourse is an important aspect of fruitful collaboration. All of these topics are addressed in detail in the standards.

There is a broader understanding of what science curriculum is in the third edition, both in terms of how it is defined and how it is lived out in classrooms. The nature of science is discussed at length. Readers will see a detailed description of teachers' pedagogical knowledge and skills. The descriptions of instruction are rich and robust, with more language about scientific investigations and how students make sense of their understandings. Safety is given greater emphasis than in previous editions of the standards, and it is defined more broadly to include emotional as well as physical safety. Careful attention is paid to the contexts of teaching and the ways in which they vary.

Science Standards, Third Edition, reflects the fundamental belief that assessment is an ongoing process that is essential to understanding students, setting goals, monitoring student progress, and evaluating the success of instruction. Choices related to all aspects of assessment—from the selection and implementation of tools to the interpretation, application, and communication of results—are analyzed. The political and emotional aspects of assessment are also addressed.

The reader will find enhanced discussion of community partnerships and a clear commitment to professionalism that goes beyond traditional definitions and boundaries. The standards also discuss reflection *in* teaching as well as reflection *on* teaching in order to prompt intense awareness of the many ways in which reflection can improve practice.

The Structure of This Edition

What were formerly separate standards documents for early adolescence and adolescence through young adulthood have now been combined into a single, comprehensive document. When aspects of understanding students, curriculum, instruction, resources, and other topics differ significantly for the different student developmental levels, those differences are attended to explicitly, often through examples. The examples are not meant to prescribe specific behaviors but rather to clarify concepts and bring teaching to life. They are intended to prompt recognition of familiar practices, stimulate imagination, and prompt innovation.

Science Standards, Third Edition, has been divided into nine standards. The numbering of the standards does not imply a hierarchy of importance; all aspects of teaching and learning elucidated in this document are equally important. Since all knowledge of students, of science, and of instruction is intertwined, the act of dividing this material into separate standards is somewhat arbitrary.

Readers should note that the concepts of reflection as well as diversity, fairness, equity and ethics are presented both as separate standards and as threads that run throughout the document. The standalone

standards dedicated to those concepts attend to general applications, whereas the references that appear within other standards are tailored to those standards specifically.

Certain threads, such as student-centered inquiry or student engagement, are embedded within many standards rather than encapsulated within a single standard. The intent is not to de-emphasize the importance of these threads, but rather to analyze these complex and multi-dimensional topics more clearly. For example, Standard II—*Knowledge of Science* examines in detail the different ways in which inquiry is fundamental to science, whereas Standard III—*Curriculum and Instruction* analyzes ways in which inquiry can be taught. Standard V—*Learning Environment*, discusses how a learning environment can facilitate scientific inquiry. This is just one example of how particular aspects of a crucial thread are highlighted in different standards.

Developing High and Rigorous Standards for Accomplished Practice

Science Standards, Third Edition, describes what accomplished teachers should know and be able to do. The standards are meant to reflect the current professional consensus about the essential aspects of accomplished practice. The deliberations of the Science Standards Committee were informed by national and state initiatives on student and teacher standards operating concurrently with the development of National Board Standards. As the understanding of teaching and learning continues to evolve over the next several years, these 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 explanations, modeling, managing the classroom, and monitoring student progress. Teaching as it actually occurs, on the other hand, 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 paradox, then, is that any attempt to write standards that dissect what accomplished teachers know and are able to do will misrepresent, to a certain extent, the holistic nature of how teaching actually takes place. Nevertheless, the fact remains: certain identifiable commonalities characterize the practice of accomplished teachers. The standards that follow are designed to capture the knowledge, artistry, proficiency, 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.

Standard Statement: This is a succinct statement of one vital aspect of the practice of the accomplished teacher of science. Each standard is expressed in terms of observable teacher actions that have an impact on students.

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.

In addition, throughout the document are examples illustrating accomplished practice and demonstrating how decisions integrate various individual considerations and cut across the standard document. If the standards pull apart accomplished teaching into discrete elements, the examples put them back together in ways more clearly recognizable to teachers. Because the National Board believes there is no single right way to teach students, these examples are meant to encourage teachers to demonstrate their own best practice.

Science Standards Statements

The National Board for Professional Teaching Standards has organized the standards for accomplished teachers of science into the following nine standards. These standards have been ordered to facilitate understanding, not to assign priorities. They each describe an important facet of accomplished teaching and often occur concurrently because of the seamless quality of accomplished practice. These standards serve as the basis for National Board Certification in Science.

Standard I: Understanding Students

Accomplished science teachers continuously seek to understand their students, and they use this knowledge to enhance student learning.

Standard II: Knowledge of Science

Accomplished science teachers have comprehensive understandings of the nature of science, inquiry, and natural phenomena.

Standard III: Curriculum and Instruction

Accomplished science teachers thoughtfully and deliberately implement a standards-based curriculum using a variety of high-quality instructional strategies and resources to enhance student learning.

Standard IV: Assessment

Accomplished science teachers purposefully assess their students in order to set learning goals, differentiate instruction, and encourage student learning.

Standard V: Learning Environment

Accomplished science teachers create and maintain a safe and engaging learning environment to promote and support science learning for all students.

Standard VI: Family and Community Partnerships

Accomplished science teachers establish productive interactions and successful partnerships with families and communities to enhance student learning.

Standard VII: Advancing Professionalism

Accomplished science teachers advance their professionalism by pursuing leadership roles, collaborating with colleagues, and undertaking high-quality professional learning opportunities.

Standard VIII: Diversity, Fairness, Equity and Ethics

Accomplished science teachers understand and value diversity, and they engage all students in high-quality science learning through fair, equitable, and ethical teaching practices.

Standard IX: Reflection

Accomplished science teachers continually reflect on their teaching practice in order to maximize their own professional growth and improve the quality of their students' learning experiences.

Standard I

Understanding Students

Accomplished science teachers continuously seek to understand their students, and they use this knowledge to enhance student learning.

Introduction

Accomplished science teachers¹ possess a deep understanding of their students' readiness for learning, developmental characteristics, backgrounds, and learning profiles—including their approaches to learning science. Accomplished teachers' appreciation of their learners is rooted in a knowledge of early adolescent and young adult learners and is refined through extensive experience working with individual students. Teachers gain insight into their students through both formal and informal activities, ranging from administering surveys to interacting with students in the cafeteria. Accomplished teachers understand that students exhibit a wide range of abilities and that individual students may excel in some respects and need support in others.

Accomplished science teachers continuously monitor their students throughout the year in order to expand their understanding. Teachers apply their knowledge of students to seek out appropriate resources, differentiate instruction, and improve learning. Accomplished science teachers use their knowledge of students to ensure that all instruction meets students at their current emotional, social, and developmental levels and supports moving them forward. Teachers frequently communicate, through both words and actions, the belief that all students can learn science.

Accomplished teachers have a genuine interest in their students. They model respect within their classroom and promote respectful behavior among their students. Accomplished teachers know that it is essential to understand students in order to meet their learning needs, and they value creating productive and positive relationships with students as vital to building community and creating an environment that is conducive to success.

¹ All references to *teachers* in this document, whether stated explicitly or not, refer to accomplished science teachers.

Academic Readiness for Learning

Accomplished science teachers perceive that their students' readiness to learn science is ever-changing rather than fixed. Accomplished teachers understand that readiness is multidimensional and that students may be ready to learn one aspect of science but not yet ready to learn a related concept or skill. For example, a student might know the general chemical equation for photosynthesis but not yet be ready to build a conceptual model to match the equation.

Accomplished science teachers realize that students' readiness for learning particular science content and skills depends on two major academic dimensions: their general academic background and their skills and knowledge specifically related to science. Accomplished teachers carefully preassess their students in regard to both of these dimensions.

Accomplished science teachers begin by obtaining a broad sense of the strengths and needs of their students in regard to reading and writing, numeracy, analytical skills, technological skills, collaboration, inquiry, and processing. Strategies for gathering this information include examining students' academic records; administering pretests; making observations; discussing students with colleagues; partnering with parents¹ to learn about students' interests, past difficulties, and successes; and conversing with students themselves. For example, an accomplished teacher striving to understand students' reading needs might consult with a reading coordinator in order to access students' reading scores.

Accomplished science teachers determine the scientific background that students bring to a particular subject or unit. Teachers are familiar with the details of the science curriculum in their school or district and the opportunities that their students have had to learn science. In the case of students who have transitioned from other schools, accomplished teachers seek to become familiar with the curriculum that students experienced. Teachers do not automatically assume that students have mastered this entire curriculum. Teachers know that students may have gaps in their understanding of some science concepts and that it is the teacher's responsibility to identify and address those gaps. For example, a student who lacks an understanding of mass and volume will need explicit, meaningful instruction in those concepts before the student can understand density. (See [Standard III—Curriculum and Instruction](#).)

Developmental Characteristics

Accomplished science teachers understand their students' sociocultural, emotional, intellectual, and physical development, and they use this extensive knowledge base to maximize instruction. Accomplished teachers keep up with current research on child development and learning. (See [Standard V—Learning Environment](#) and [Standard VII—Advancing Professionalism](#).)

¹ The terms *family* and *parent* are used throughout this document to refer to people who are the primary caregivers, guardians, or significant adults in the lives of children.

Accomplished science teachers are aware that a student's degree of social and emotional confidence influences learning. Teachers understand the social and emotional needs typical of the age group that they teach, and they comprehend how these needs impact classroom dynamics. For example, teachers understand that the social inclinations of their students affect how productively they can work in groups. Teachers are sensitive to developmental issues related to self-image, societal expectations, family structure and dynamics, and changing peer influences. Accomplished teachers are intentionally aware of current adolescent trends and cultural changes, and they know how to appropriately incorporate aspects of preteen, teen, and young adult culture into science education.

Accomplished science teachers understand that their adolescent students become increasingly capable of sophisticated thought, such as abstract and spatial reasoning, over time. Teachers make the effort to discern the intellectual capabilities of students, understanding that students' cognitive abilities may vary dramatically. Because accomplished teachers know that their students are beginning to become aware of their own thought processes, they understand the benefits of providing students with opportunities to assess the strengths and weaknesses of their own approaches to problem solving.

Accomplished science teachers understand that developmental progress can vary greatly across the population, and that there are no distinct boundaries dividing early adolescents and young adults. For example, a given 17-year-old could be less developmentally ready to comprehend scientific concepts than a particular 11-year-old. Accomplished teachers combine their knowledge of developmentally appropriate, age-based strategies with their own observations in order to differentiate instruction in a way that is appropriate for their students. Accomplished teachers can provide evidence of how they differentiate content, processes, and products to accommodate their students' developmental differences. (See [Standard III—Curriculum and Instruction](#).)

Accomplished science teachers understand that physical development affects how a student thinks, behaves, is treated, and learns in the classroom. For example, a smaller student who appears younger may be treated as less mature intellectually than the student actually is. Accomplished teachers make modifications to the classroom environment and instructional strategies to accommodate the physical changes that their students are experiencing. These teachers also invite parents and colleagues to assist in supporting students during these changes. (See [Standard V—Learning Environment](#).)

Learning Profile

Accomplished science teachers are aware that students have different learning profiles, and teachers choose or design curriculum and instructional strategies that give educational access to all students. Accomplished teachers adjust to the varied learning styles and personality profiles of their students. Teachers are proactive in learning about the exceptionalities and language needs of their students as they

relate to their students' learning goals and specific accommodations. They know how to support and challenge gifted and talented students, English language learners, students with exceptional needs, and others. Accomplished teachers design instruction that emphasizes students' strengths and raises their abilities in areas that are not as strong. Accomplished science teachers also understand that students choose to use their knowledge and skills in many different ways and provide opportunities for students to do so. (See [Standard III—Curriculum and Instruction](#) and [Standard VIII—Diversity, Fairness, Equity, and Ethics](#).)

Accomplished teachers are aware of what engages and motivates their students, and they use this knowledge to plan instruction. Accomplished teachers make use of their students' strengths and preferences to help them learn science. For example, a teacher might give students opportunities to use art, music, storytelling, building, crafting, and technology to explore and apply their understandings of natural phenomena.

Relevant Student Background

Accomplished science teachers are sensitive to how students with diverse abilities, interests, experiences, linguistic heritages, socioeconomic statuses, ethnicities, religious traditions, sexual orientations, body images, geographic references, and family backgrounds and configurations come to understand science. Accomplished science teachers realize that whereas some aspects of a student's background are obvious, others are subtle or even hidden. Furthermore, even if an issue is not particularly sensitive with regard to the student, it may be sensitive with regard to a friend, sibling, or loved one. Accomplished teachers understand their students' backgrounds, but they also make a strong effort to be tactful in their discussion of all sensitive issues.

Techniques for Learning about Students

Accomplished science teachers are aware of the many ways they can learn about their students. Teachers are proactive in soliciting feedback directly from students to determine their learning styles, their abilities, and the activities they prefer. Teachers may use autobiographies, questionnaires, interviews, and conversations to elicit this information. By knowing their students, accomplished teachers find ways to make science content and instruction both valuable and meaningful.

Accomplished science teachers are aware of the changing nature of student strengths and needs; thus, teachers continually look for information by examining student work and communicating with colleagues and parents to better understand their students. In addition to accessing individual student data, teachers make efforts to learn about the sociocultural aspects of students' communities. If information is not easily available, accomplished teachers are creative and persistent in seeking out other resources.

Diversity, Fairness, Equity, and Ethics

Accomplished science teachers use their knowledge of students to ensure an equitable and fair classroom. Teachers ensure that they meet the needs of all students while maintaining high expectations for all. Accomplished teachers make an effort to uncover their own assumptions and biases and do not allow them to interfere with student learning. Teachers make a concerted effort to expose all students, especially traditionally underserved students, to a variety of learning experiences, such as summer opportunities, workshops, speaker series, and internships, so they can recognize that science is an important part of their lives. Science teachers encourage all students to see that they can pursue science and science-related careers, and teachers often act as mentors or seek out other appropriate mentors for students.

Accomplished science teachers use their understanding of students to address issues of diversity in their teaching. They learn about and show respect for students' belief systems, especially when addressing controversial subjects. Teachers are sensitive to the ways they discuss different family structures. When it is appropriate to do so, they link issues in science with students' personal and cultural backgrounds, being sure to do so in a way that recognizes the complexity of these interactions.

Accomplished science teachers are sensitive to the confidential nature of personal student information. They are knowledgeable about the ethical and legal responsibilities related to their knowledge of students; for example, teachers know what they are legally required to report in an effort to protect and keep their students safe. Accomplished teachers carefully follow ethical guidelines regarding the sharing of information. For example, they keep their students' grades, medical records, IEPs, and other personal information confidential. Accomplished teachers educate other teachers in these areas and advocate for sensitivity and confidentiality related to student information. Accomplished teachers model discretion for all of their colleagues. For example, they intervene tactfully but firmly if they overhear other teachers discussing students in a public space such as a hallway. (See [Standard VIII – Diversity, Fairness, Equity, and Ethics](#).)

Reflective Practices

Accomplished science teachers continuously reflect on how well they know their students and how they use this information to inform their instruction. Through daily instructional and assessment practices, accomplished teachers reflect on their students' readiness for learning in relation to specific goals. They reflect on how best to identify content gaps, literacy levels, and other elements that contribute to readiness, and they use this information to develop lesson plans and select instructional materials. Accomplished science teachers reflect on whether they have differentiated instruction and assessment to ensure that readiness needs have been addressed.

Accomplished science teachers reflect on their ability to identify the developmental stages their students are going through and how they use this understanding to frame

instructional practices. Teachers understand that the developmental process varies greatly among their students and reflect on the degree to which their instructional activities are supportive of these differences.

Accomplished science teachers realize that reflecting on learning profiles is a vital part of understanding the whole student. Accomplished teachers reflect on their knowledge of the wide range of learning styles and preferences that exist in their classrooms. They determine if student needs are being met by looking for understanding during science discourse and by assessing students' abilities to answer complex questions. When teachers determine that there are student needs that they cannot address by themselves, they reflect on ways to obtain additional information and ideas from colleagues and others.

Accomplished science teachers reflect on what they know about their students' backgrounds and how they implement this knowledge to enhance student learning. They reflect on how they can update their understandings of exceptionalities and other aspects of students' backgrounds through professional development, conversations with colleagues, and other appropriate means.

Accomplished science teachers reflect on the techniques they use to learn about students. They ponder whether their techniques effectively elicit the information they are seeking. Teachers also reflect on how they can make the process of learning about students appropriately transparent and seamless.

Accomplished science teachers reflect on the degree to which they are aware of and responsive to the diversity within their classroom. They reflect on the assumptions they make about their students, possible biases they possess, and how they can use their knowledge of students' backgrounds to ensure a fair and equitable learning experience. Accomplished science teachers reflect on whether they have provided accommodations and flexibility in their instructional practices in such a way as to reach their students. Accomplished teachers reflect on their sensitivity in exploring and discussing their understanding of students.

Standard II

Knowledge of Science

Accomplished science teachers have comprehensive understandings of the nature of science, inquiry, and natural phenomena.

Introduction

Accomplished science teachers realize that the goal of science education is to cultivate scientifically literate adults, and they know that productive learning is structured around knowledge of the nature of science, the process of inquiry, the context of science, and science content.

The Nature of Science

Accomplished science teachers know that scientific thought is multifaceted and that science is a way of knowing about natural phenomena. Science educators have identified a core set of concepts that express the nature of science: science is reliable and yet tentative; science is based on empirical evidence; science relies on observations and inferences; science utilizes theories and laws; scientific knowledge is generated through multiple methods; science is a creative and imaginative human endeavor; and science is a human activity that takes place within a cultural, political, and economic context.

Accomplished science teachers understand science as an expression of the deep human impulse to explore and learn ever more about natural phenomena. Teachers have a thorough grasp of science as a sense-making activity, that is, an approach to building a consistent, testable set of understandings about natural phenomena. Accomplished teachers are aware of the many complex ways in which scientific knowledge is generated, such as through experiments, correlational studies, and observations; they understand that there is no simple scientific method through which all scientific understanding is achieved. Accomplished teachers know how to apply scientific understandings to engineering practices. They also know how to help their students develop an understanding of the nature of science and to use this understanding to make informed decisions in their daily life.

Accomplished science teachers realize that in order for students to understand the nature of science, students need to engage in hands-on investigations. However, teachers also know that students do not develop an understanding of the nature of science through investigations alone; they require explicit instruction. For example, through an investigation of a pendulum, an accomplished teacher might illustrate

how scientific knowledge is built on empirical evidence. The teacher would help students understand how the observations they make of a specific pendulum can be used to create a general model that can be used to predict and describe the behavior of all pendulums. The teacher could subsequently provide opportunities for students to apply their model in order to discover its strengths and its limitations. (See [Standard III—Curriculum and Instruction](#).)

Understandings about Inquiry

Accomplished science teachers understand that inquiry is important to science classrooms for two basic reasons. Inquiry is both the process scientists use to learn about natural phenomena and a process that students can use to develop their knowledge of science content and their metacognition related to the field of science. (See [Standard III—Curriculum and Instruction](#).)

Accomplished science teachers understand that scientists use inquiry to learn about natural phenomena. Scientific inquiry involves making observations; posing questions; examining books and other sources of information to see what is already known about a given subject; planning investigations; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results. Inquiry requires the identification of assumptions, the use of critical and logical thinking, and the analysis of alternative explanations. Inquiry must be undertaken with consideration for the ethics of the scientific process.

Accomplished science teachers provide students with multiple opportunities to engage in scientific practices, including inquiry. They teach students how to develop scientific questions, design and conduct investigations, obtain and analyze meaningful data, and arrive at conclusions. (See [Standard III—Curriculum and Instruction](#).)

Accomplished science teachers know that their students need more than the ability to conduct scientific inquiry. Students need to possess a deep understanding about the capacity of scientific inquiry to generate knowledge, solve problems, answer questions, generate new questions, and enhance collaboration. Accomplished teachers facilitate the process through which students learn to combine their ability to conduct investigations, their understandings about scientific inquiry, and their critical thinking skills to further their own scientific understandings.

Context of Science

Accomplished teachers realize that there are many different lenses through which science can be viewed, including historical, personal, sociocultural, technological, and ethical perspectives.

Accomplished science teachers make sure that students develop a rich and diverse historical perspective on science in order to understand how science developed as a discipline. Teachers provide students with evidence that scientific understandings are continually built upon prior knowledge. Historically, scientific

advancements have resulted from collaboration among the disciplines of science, mathematics, technology, and engineering. A historical perspective makes students aware of the impressive technological achievements of early cultures and the substantial contributions of women and men from different cultural groups. For example, a teacher might point out the contributions of Islamic cultures to the fields of astronomy and medicine and the discovery of papermaking in China more than two thousand years ago.

Accomplished science teachers realize that presenting science as a human endeavor enhances students' appreciation of scientific progress. Accomplished science teachers acquaint students with the biographies and perspectives of scientists who have made major discoveries and helped shape our world. Teachers might use biography to help students perceive how scientists such as the following overcame adversity to advance the understanding of science: Percy Julian, an African American who was the inventor of synthetic cortisone and drugs to treat glaucoma; Shirley Jackson, who was the first African American woman to receive her Ph.D. from M.I.T; and Fred Begay, a Navajo, who is known for the alternative use of lasers and electronic ion beams to heat thermonuclear plasma.

Accomplished teachers connect science to sociocultural perspectives that are meaningful to students. Accomplished teachers know that science is a collaborative enterprise that depends upon sharing knowledge. Scientific endeavors reflect the social and cultural issues that predominate at a given time. Teachers connect the unifying concepts of science to such areas as personal and community health, population growth, utilization of natural resources, environmental quality, naturally occurring and human-induced hazards, and science and engineering in local, national, and global scenarios. For example, a science teacher might relate the biological impacts of drug and alcohol use to community concerns related to these substances.

Accomplished science teachers are aware of the interdependent relationships that exist among mathematics, technology, and engineering. Teachers explain how advances in scientific knowledge lead engineers to develop new technologies and vice versa. Accomplished teachers ensure that students know that science and technology, while related, are pursued for different purposes. Whereas science seeks to understand natural phenomena, technology and engineering are often driven by the need to solve human problems.

Accomplished teachers help their students understand the impact that scientific discovery has on society and the ethical responsibility of scientific investigation. For example, teachers might include case studies of technology-generated changes such as space travel or might have students debate controversial issues such as cloning or nuclear power. In addition, accomplished teachers might provide opportunities for students to address ethical responsibility within their own community by investigating an issue such as the deforestation of a local area.

Teacher Content Knowledge

Accomplished science teachers possess a strong understanding of the concepts, themes, principles, laws, theories, terminology, and factual information that demarcate the specific bodies of scientific knowledge that they are responsible for teaching. They also understand how those bodies of knowledge connect with other scientific disciplines. Accomplished science teachers recognize the importance of mathematics in science and are able to make its application visible to their students. For example, an accomplished teacher would be able to apply algebra to stoichiometry or calculating the speed of an object, geometry to vector analysis or the refraction of light, statistics to determining averages, and probability to Punnett squares. Accomplished teachers stay well informed about current research and developments in science. Teachers understand the role that technology and engineering play in shaping the constructed environment, human interactions, and daily life.

Not only do accomplished teachers have a deep understanding of the specific content knowledge they teach, but they also comprehend the unifying concepts and processes that cut across all areas of science, including cause and effect, systems, patterns, quantity, energy and matter, stability versus change, and structure and function. While instructing their students in the specific subject matter of science, accomplished teachers continually refer to these big, crosscutting concepts, emphasizing their ultimate importance.

All accomplished science teachers possess an understanding of core ideas in the following aspects of science.

Earth and Space Sciences

Accomplished science teachers understand the current theories about the origin, composition, and structure of the universe and the motion of the objects within it. They also understand that many of the phenomena observed on Earth involve interactions among components of air, water, and land that are driven by the transfer of energy. Accomplished teachers realize that various cycling processes shape the Earth's surface, and they understand the relationship of these processes to environmental conditions in the Earth's atmosphere, oceans, and land masses. Accomplished teachers understand earth and space science through an interacting systems approach.

Life Sciences

Accomplished science teachers understand the diversity and unity that characterize organisms; the genetic basis for the transfer of biological characteristics from one generation to the next; the structure and function of cells; the organization and physiology of living organisms; the dependence of all organisms on one another and on their environment; the flow of energy and matter in the living environment; the behavior of organisms; the basic concepts of the evolution of species; and the consequences of species loss.

Physical Sciences

Accomplished science teachers understand the basic properties of matter and the principles governing the interactions between matter and energy and between matter and other matter; the conservation of energy and energy transfer; motion and the principles that explain it; the nature of atoms and molecules and the behavior and interactions between them; the forces that exist between and within objects and atoms; and waves and their applications.

Depth of Knowledge

Accomplished science teachers have in-depth knowledge of those disciplines they teach in addition to a foundation of scientific knowledge in all of the disciplines. Consider the example of clouds and precipitation. Accomplished science teachers know how the water cycle affects the origins of water vapor in the atmosphere; the principles of evaporation, condensation, and convection; the fact that different cloud types are related to various weather patterns; and the phenomenon and causes of acid rain. However, teachers specializing in earth, environmental, and space sciences have a greater depth of understanding of how natural phenomena such as volcanoes produce emissions of nitrogen and sulfur oxides and how these atmospheric pollutants can impact air and water quality. Teachers specializing in the life sciences have a deeper knowledge of the effects of acid rain on the ecosystem and on the structures and functions of various organisms. Teachers specializing in the physical sciences know more specific information about how acid anhydrides dissolve in water and react with carbonates and metals or how rain falls at a constant velocity when the forces on it are balanced. Regardless of their particular specializations, accomplished teachers understand the relationship of the topic of clouds and precipitation to the crosscutting concepts of energy and matter, flows, cycles, and conservation.

Accomplished science teachers at both the early adolescent and the adolescent-young adult levels ensure that they have the necessary knowledge and skills to teach the curriculum and meet the cognitive needs of students. If a gap in their own scientific understanding is identified, teachers seek out formal or informal science learning opportunities (such as college classes, workshops, conferences, research experiences, and opportunities that combine pedagogy and science) to deepen those understandings. As naturally curious lifelong learners, accomplished science teachers continually expand their content knowledge to remain current and enhance their students' science learning. (See [Standard VII—Advancing Professionalism](#).)

Accomplished science teachers recognize that the overall coherence of their understanding is more valuable than mere recall of fact. The knowledge base of accomplished science teachers is highly integrated.

Reflective Practices

Accomplished teachers reflect on the nature of science. These teachers reflect on their understanding of science as a human endeavor to understand natural

phenomena. They try to determine how well they incorporate the tenets of science in their instruction. Accomplished teachers reflect on how the nature of science is represented in the curricular choices they make, and the degree to which students demonstrate an understanding of the nature of science. Accomplished teachers monitor how often they use explicit instruction to make connections for students between classroom investigations and the nature of science. Teachers analyze the opportunities they give students to experience the nature of science in their science activities, and teachers evaluate the ways in which they attempt to make those experiences more transparent to their students.

Accomplished science teachers reflect on their understanding of inquiry. They think about the degree to which they guide students in making connections between classroom investigations and understandings about scientific inquiry. Teachers monitor not only students' understanding of content but their understanding of the practice of science, which includes scientific inquiry. Accomplished teachers also reflect on the frequency and extent of opportunities for students to engage in scientific inquiry. Accomplished teachers reflect on how often their learners engage in making observations; posing questions; referencing other data; planning investigations; using tools to gather, analyze, and interpret data; developing hypotheses and justifying claims; and communicating results.

Accomplished teachers reflect on how their own content knowledge and pedagogical knowledge support the practice of teaching science. These teachers reflect on their depth of comprehension and monitor their developing scientific understandings. In specific areas where they perceive gaps in their content knowledge, accomplished teachers participate in professional learning opportunities. Accomplished teachers reflect in order to identify authentic applications of content understandings to real-world situations. Finally, accomplished teachers reflect on their role as lifelong learners and the ways in which they model a commitment to learning science.

Standard III

Curriculum and Instruction

Accomplished science teachers thoughtfully and deliberately implement a standards-based curriculum using a variety of high-quality instructional strategies and resources to enhance student learning.

Introduction

Accomplished science teachers realize that the term curriculum has no single, simple definition or universal meaning. Curriculum has many dimensions and educators view it through many different lenses. Accomplished science teachers recognize that a high-quality science curriculum includes standards-based content plus scientific skills and practices. The curriculum also consists of learning goals and objectives and the pacing for delivering content and skills. Accomplished teachers realize that curriculum is more than the content that teachers deliver; curriculum consists of systematically planned and guided learning opportunities that are different for each student. Accomplished teachers know that a robust curriculum develops in students deep understandings of natural phenomena and the ability and willingness to apply those understandings to complex, real-world problems.

Accomplished science teachers deliver curriculum through thoughtful, well-intentioned instruction. Teachers deliberately employ a variety of research-based instructional strategies, and they select, adapt, and create instructional resources that support active student exploration and understanding of science. Accomplished teachers act as facilitators of students' intellectual explorations, guiding students toward scientifically valid mental constructs about the natural and engineered worlds. Teachers create a space where students can flourish by encouraging them to take responsibility for their own learning and by promoting scientific discourse among students. Accomplished teachers make the process of inquiry central to their instruction.

Curriculum

Accomplished science teachers recognize the hallmarks of a well-developed curriculum. It must be aligned to national and state standards and to the unifying concepts of science. (See [Standard II—Knowledge of Science](#).) It must be developmentally appropriate, culturally relevant, and pedagogically sound. It must encompass strategies for building conceptual understanding and opportunities for inquiry. A high-quality science curriculum is purposefully designed, is based on a

sequential progression toward scientific understanding, and allows for multiple access points for different students. The ultimate goal of science education and thus of a high-quality science curriculum is to develop members of society who can apply their science understandings to their daily lives.

Accomplished science teachers make many curricular decisions, whether or not they have the opportunity to select their textbooks, select standards-based content, or determine sequence and timing. Teachers make curricular decisions such as selecting ancillary materials, organizing outside resources such as field trips, providing enrichment activities for students with exceptional needs, making modifications in sequencing, contextualizing lessons for the local population or specific student needs, and making cross-disciplinary connections. Teachers base curricular decisions on considerations such as the availability of resources; the characteristics of high-quality curriculum materials; standards; current research on how students learn science; and the assessed needs of students, teachers, and the community. Teachers recognize the complexities of teaching and learning science, and they select, design, and utilize curriculum materials that support rigorous and relevant science instruction, meet the needs and interests of diverse learners, and engage students.

When it comes to choosing, developing, or enhancing the curriculum, accomplished science teachers see themselves as members of a learning community. They collaborate to plan and develop comprehensive science programs. Whenever possible, teachers take advantage of opportunities to develop or select science curricula, advocate for purposeful curricular choices aligned with standards, and seek out information about the known effects of the curriculum on student learning. Teachers may augment the existing curriculum to provide opportunities for students to further explore additional relevant or engaging science topics in order to deepen core conceptual understandings. Accomplished teachers are mindful of curricular goals and use them to guide instruction.

Instruction

Philosophy and Important Principles

Accomplished teachers have deep science content knowledge and specific pedagogical content knowledge that they apply to provide high-quality instruction. Accomplished teachers use instructional strategies that match the thinking required by the curriculum and the needs of the students. Teachers are able to make connections between the curriculum and students' prior experiences, prior knowledge, and everyday understandings.

Accomplished science teachers draw on their knowledge of crosscutting principles such as patterns of change and cycles to help students identify connections across science disciplines. Teachers make learning relevant by connecting science lessons to current or historical events. Accomplished science teachers realize that the process of making meaningful connections supports conceptual understandings that help develop the unifying concepts of science.

Accomplished science teachers mirror the processes that scientists use in their efforts to understand the world; by doing so, teachers help students develop an understanding of how scientific knowledge is generated. Teachers guide students to develop the habits of mind of scientists, the capability to engage in scientific inquiry, and the skills to reason in a scientific context. Accomplished teachers understand that, ultimately, students should be able to hypothesize, model, develop explanations from evidence, and engage in scientific discourse. Students should also become critical consumers of scientific information. (See [Standard II—Knowledge of Science](#).)

Accomplished science teachers instruct their students in scientific inquiry. Teachers realize that establishing an inquiry-based classroom helps students develop deep understandings of science and a sense of ownership over their own learning. Accomplished teachers foster their students' intellectual independence—at first, modeling and demonstrating thought processes for students, and gradually making way for increasingly student-generated questions. Teachers understand that self-directed learners become more effective lifelong learners. Accomplished teachers also understand that students' ability to apply knowledge to novel situations is directly related to the depth of their understanding of what they have learned.

Methods and Strategies

Accomplished science teachers identify and use appropriate methods and strategies to improve student learning. They develop an instructional framework of short- and long-term goals based on each student's knowledge and abilities. Teachers involve their colleagues and the students themselves in this process. Teachers use assessment to select appropriate individual and classroom goals and strategies and to determine whether those goals have been met and those strategies have been effective. Planning is based on department or schoolwide data as well as data collected from whole-class and individual assessments. (See [Standard IV—Assessment](#).)

Accomplished teachers understand student conceptual development and often anticipate and solicit student preconceptions—whether accurate, inaccurate, or underdeveloped—related to a given topic. When necessary, teachers take steps to help students reconstruct their thinking through appropriate activities that show the discrepancy between their original conceptions and more scientifically accurate explanations.

Accomplished science teachers use a variety of means to engage students in learning. They frame the content of their lessons with intriguing examples relevant to students' everyday lives, such as current events, pop-culture references, and modern technology. Teachers use essential questions to focus student thinking and foster intellectual curiosity. Accomplished teachers understand that students will be motivated to perform best when instruction is appropriately challenging; therefore, teachers provide opportunities for students to work at a level of difficulty that is slightly above their comfort level. Accomplished teachers understand that students come with different interests, readiness levels, and learning profiles, and teachers

tailor instruction to maximize learning. Teachers foster student interest by having students make predictions before starting investigations, exploring questions that have meaning to students' lives, and using discrepant events that confound students' expectations. (See [Standard I—Understanding Students](#).)

Once students are engaged in a topic, accomplished teachers create a space in which students can explore their ideas. Through lab experiments; field experiences; simulations; physical and mental models; regional, state, and international science and engineering competitions; and other methods, teachers involve students in conducting their own scientific investigations. Teachers use cognitively appropriate scaffolds to support guided investigations, including inquiry. Student explorations take place through hands-on experiences, interactive lectures, or thought experiments. Teachers guide students to propose tentative claims based on their evidence and reasoning. (See [Standard II—Knowledge of Science](#).)

Accomplished science teachers understand that in order for students to learn how to view the world through a scientific lens, they must have abundant opportunities to practice the myriad skills involved in scientific inquiries. Accomplished teachers understand the continuum of scientific inquiry, from highly teacher-directed to student-led investigations. Teachers know the instructional value of using different levels of inquiry in teaching, and therefore they deliberately structure investigations to match student abilities. Teachers scaffold the development of scientifically oriented questions by providing question stems and instruction on how to identify rich and robust, testable questions. They help students understand that different kinds of questions lead to different types of scientific investigations. For example, a student question such as “Does ice melt faster in different liquids?” leads to a controlled experiment; whereas a question about how water evaporates and condenses may lead a student to construct a physical model to demonstrate their current scientific understanding. Investigations may range from observing and describing objects, organisms, or events to collecting specimens, conducting experiments, and collecting data. Teachers support students in developing and using physical and mental models to understand natural phenomena. Accomplished teachers know that students must have frequent opportunities to take part in science investigations, and that these investigations must be followed by designated time for students to reflect on the significance of what they have done. Accomplished teachers promote long-term investigations and authentic student research in and beyond the classroom. These could range from technologically advanced professional laboratory experiences to field observations on school grounds.

Accomplished science teachers teach students effective methods for documenting, communicating, and justifying their explanations. These methods include but are not limited to writing laboratory reports, preparing presentations and posters with graphs and visual displays, and making documentaries. Teachers help students learn how to interpret and draw conclusions from both qualitative and quantitative data. Teachers anticipate that when their students pursue open-ended inquiry, the results will be unpredictable, and teachers are willing to facilitate students in making sense of whatever data emerges. Engaging in the processes of

science implies experiencing all the sensations of scientists, including frustration and confusion; accomplished teachers help students navigate the obstacles as well as the triumphs of inquiry.

Accomplished science teachers are skilled at employing meaningful classroom discourse to help students understand science, reflect on how their ideas have changed as a result of instruction, and uncover and resolve persistent naive conceptions. Teachers initiate and facilitate discussions. They use skillful questioning and provide clear explanations, prompt students to question each other, and encourage healthy but polite skepticism. Through purposeful conversations, students of accomplished teachers refine, articulate, and elaborate their own understandings of natural phenomena while developing an understanding of the rules of evidence and the modes of argument that guide the inquiry process. Students learn to communicate complex scientific ideas using appropriate academic and scientific vocabulary.

Accomplished science teachers make corrections when an activity falters and seamlessly improvise when an unanticipated learning opportunity presents itself. They willingly allow student thinking to drive a lesson but make sure that 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.

Accomplished teachers invite students to explore science connections across the curriculum rather than adhere rigidly to disciplinary boundaries. Teachers understand that deepening students' knowledge of the world, ability to use language, understanding of technology, command of mathematics, and growth in science literacy are inextricably intertwined processes. Teachers regularly encourage students to apply the abilities and understandings of scientific inquiry across every facet of the school curriculum. Applications could range from analyzing the impact of a historical event on a particular scientific development to conducting large-scale interdisciplinary projects involving multiple content areas.

Accomplished science teachers realize that it is their responsibility to teach students certain literacy and mathematics skills. For example, students need explicit instruction in how to read a scientific text and how to write a lab procedure. Teachers help students learn how to comprehend highly technical scientific terminology and how to interpret visual features such as diagrams and charts. Teachers model how to use evidence and claims in scientific writing. Additionally, accomplished teachers provide explicit instruction in the application of mathematical tools to science. They help students learn mathematics in the context of science explorations; their students learn to use mathematical reasoning skills to discern relationships in scientific data. This includes applying mathematical formulas, graphing and interpreting relationships, and using scale and proportion.

Resources and Instructional Materials

Accomplished science teachers are innovative in their ability to select, adapt, and create instructional resources—including print, laboratory, technology, and community resources—that support active student explorations of science. Accomplished teachers use instructional resources to engage students in meaningful learning and to support multiple learning styles. For example, when teaching about the seasons, an accomplished teacher may use texts, diagrams, access to a planetarium, globes and flashlights representing the Earth and Sun, or digital simulations to help students understand the relationship between the tilt of the Earth and the seasons.

Accomplished science teachers use a variety of text resources to support instruction. These resources may include textbooks, periodicals, peer-reviewed journals, and digital literature. Teachers use these materials to support the development of student literacy and to deepen conceptual understanding.

When helping students engage in the processes of science, accomplished teachers provide students with equipment and other resources as similar as possible to those used by practicing scientists. For example, teachers provide students with electronic data-collection devices, professional glassware, and microscopes when these are available. Accomplished teachers may leverage community connections to expose students to authentic research through apprenticeships, shadowing experiences, virtual and physical field trips, or guest speakers.

Accomplished science teachers understand that, due to technology, there has been a rapid increase in the availability of information related to science. Accomplished teachers actively seek to have students take advantage of the constantly evolving tools of technology. They teach students how to identify, retrieve, evaluate, use, and synthesize reliable and relevant information from multiple sources. Teachers model strategies for determining the credibility of information, particularly when students are using the Internet.

Diversity, Fairness, Equity, and Ethics

Accomplished science teachers understand that science needs to be accessible for all students, regardless of their culture, gender, socioeconomic background, learning abilities, language, or career aspirations. Teachers ensure fairness in the classroom by providing all students with equitable access to high-quality curriculum and instruction.

When designing or choosing curriculum and implementing instruction, accomplished science teachers accommodate students' sociocultural needs and backgrounds through a combination of culturally relevant and culturally responsive teaching. Culturally relevant teaching refers to the deliberate planning and employing of curriculum materials and instructional strategies based on students' cultural experiences. Culturally responsive teaching occurs when teachers use students' knowledge and experiences to modify or expand instruction. For example, a teacher

in a community in the southwestern United States where adobe house construction is widespread might ask students why thick walls are useful in a hot climate. The teacher could then use student responses as a springboard to an investigation of the insulating properties of various construction materials and the scientific principles underlying insulation.

Accomplished teachers know their students' background experiences, understand each student's background, and respond quickly to address student needs. For example, during a lesson on energy, a teacher might recognize that some students have no familiarity with roller coasters—a traditional example used to illustrate energy transfer. An accomplished teacher would purposefully provide a common experience such as a pendulum demonstration to illustrate the concept to the broadest possible audience.

Accomplished science teachers are aware of socioeconomic disparities within the classroom. They are mindful of their expectations of students with regard to modes of transportation, school supplies, and availability of time outside of class. They work tirelessly to create opportunities so students are in a position to succeed. For example, in the case of students who are not able to afford field-trip fees, an accomplished teacher would obtain the necessary funds through donations or other fundraising. The teacher would address socioeconomic disparities in a sensitive and professional manner.

Accomplished teachers know that some students can bring rich insights to the classroom based on where they have lived or traveled. Immigrants, refugees, students of migrant families, and students with extensive travel opportunities can bring different perspectives to the classroom. For example, students who have lived in or visited the countryside may have a clearer visualization of the stars at night than students who have grown up in urban areas, whereas students who have seen the ocean may have a better understanding of ocean waves than students who have always lived inland. Accomplished teachers realize that diverse perspectives arise from far more than just geographical backgrounds, and they give all learners opportunities to share their experiences and observations for the enrichment of their peers.

Accomplished science teachers understand that inquiry is one instructional strategy that can be a powerful tool for addressing diversity, ensuring fairness, and promoting ethics. Through inquiry, teachers can link the crosscutting concepts of science with the social implications, ethical ramifications, and societal impacts of science. Teachers help students connect scientific knowledge to such concerns as personal and community health; population growth; natural resources; environmental quality; human-induced hazards; and science and technology in local, national, and global challenges. For example, if the local community were considering a new development project in a wetland, students might research the topic and engage in community discourse regarding the issue.

Accomplished science teachers recognize their ethical responsibility to act with impartiality in regard to sensitive subject matter. For example, a teacher might present scientific knowledge related to embryonic stem cells but would scrupulously avoid infusing the discussion with any references to the teacher's personal beliefs about the moral decisions related to how stem cells should or should not be used in medicine. Teachers also provide opportunities for students to wrestle with the ethical dimensions of science in order to improve their understanding of the nature of science.

Reflective Practices

Accomplished science teachers are reflective practitioners who constantly strive to become masters of their professions by analyzing and evaluating student outcomes in order to determine the effectiveness of their teaching. As teachers reflect on their practice and assess their effectiveness, they adapt, revise, and strengthen their instruction and curriculum to better meet the needs of students.

Accomplished teachers reflect on whether their curriculum is meeting instructional goals and objectives. They ask themselves if students are meeting the standards and are prepared for the future. When teachers find that the curriculum does not meet their expectations, they seek ways to enhance the curriculum or advocate for improvements in the adopted curriculum.

Reflective science teachers make use of many opportunities to analyze their own instruction. They may maintain a journal, videotape and watch their own teaching, or enlist a peer to observe their classroom. They reflect on whether the methods and strategies used in delivery of science curriculum are effective. While reviewing their instruction, they seek evidence of student engagement and learning. They look to see that not only does their instruction match the learning goals, but that it engages the learner, provides for learner exploration, facilitates sense making, and offers opportunities for applications.

Accomplished science teachers reflect in teaching by making on-the-spot adjustments to their planned instruction when necessary. For example, during a lesson about cell reproduction, a teacher might realize that the students do not understand why organisms need to produce more cells to grow rather than simply having their existing cells get larger. The teacher might then improvise, creating an analogy between the nucleus of the cell and a cell phone tower. The teacher would prompt a discussion of the fact that the farther away one is from a cell tower, the more difficult it is to get a signal. Students would then realize as a cell grows, it becomes harder for the nucleus to send signals related to cell functions to those organelles that are far away.

Accomplished science teachers can explain not only what they have taught and how they taught it, but why they chose specific instructional strategies. For example, a concept such as the water cycle can be taught in a variety of ways. An accomplished teacher might provide a partially completed diagram to allow visual learners to show

their understanding by coloring, labeling or completing the diagram. Another student might be encouraged to demonstrate their knowledge of the topic through a video or by creating a poem or story. Students who are kinesthetic learners might be given the opportunity to investigate the water cycle by creating a working model to share with the class. Each strategy should give students opportunities to pose and investigate questions as well as to provide context for scientific discourse. Regardless of the selected strategies, accomplished teachers reflect on how effective the approach was at generating student understanding of the topic and what might be done to improve the process in the future.

Accomplished science teachers reflect on the instructional resources they have employed to ensure that the resources support active student learning. Teachers look for ways to update resources as well as ways to use resources more effectively—including improving student access to resources.

Accomplished science teachers pay careful attention to whether the opportunities for student inquiry engage all students in learning science. They reflect on whether their instruction encourages students to take responsibility for their own learning. Teachers analyze their effectiveness in fostering student discourse about science. Accomplished teachers also reflect on whether students are able to think scientifically and apply their knowledge and skills meaningfully.

Standard IV Assessment

Accomplished science teachers purposefully assess their students in order to set learning goals, differentiate instruction, and encourage student learning.

Introduction

Accomplished science teachers view assessment as an integral part of the science learning process. They know that when assessment practices are purposeful and well designed, they have the power to support deep student learning and breadth of application. Accomplished teachers believe that when assessment is used appropriately, it can benefit both teacher and students.

Accomplished science teachers know that assessment refers to the gathering of information on students' thinking, which a teacher then uses to make instructional decisions. Assessments range from spontaneous observations of students, to carefully designed questions to probe student understanding, to project-based assessments.

Accomplished science teachers see assessment as a recursive process that occurs before, during, and after instruction. Teachers know the appropriate concepts and skills to assess at different points in the instructional sequence, selecting the most effective forms of assessment for their students. By giving students appropriate ways to show what they know and what they can do, teachers gain meaningful records of the pulse of the classroom's intellectual life. By providing relevant and timely feedback from assessments, accomplished science teachers guide student learning. In the practice of accomplished science teachers, assessment and the daily flow of instructional activity are so intertwined that they are difficult to distinguish.

Accomplished science teachers recognize that the ultimate purpose of assessment is to ensure that students are meeting high, worthwhile goals informed by current standards and understandings in the science education community. Teachers effectively utilize assessments that have a variety of purposes and structures. When necessary, accomplished science teachers adapt their assessment tools and strategies to meet the diverse needs of students. Accomplished teachers are skilled at interpreting and applying the results of assessments, and they communicate assessment results clearly to students, parents, and other concerned adults.

Functions of Assessment

Accomplished science teachers use assessment for a variety of purposes: to determine students' prior learning; to analyze students' learning and cognitive styles; to uncover students' conceptual development; to set goals; to determine instructional methods and select resources; to evaluate the effectiveness of instruction as it is taking place and make any necessary modifications; to help students monitor and reflect on their progress in order to initiate steps for improvement; to make value judgments such as assigning grades at the end of a lesson, unit, or course; and to plan for the future. Assessments help inform instructional practices, and the assessment plans of accomplished science teachers provide flexibility for modifications as needed due to student response to instruction.

Assessment tools help accomplished science teachers better understand the science skills, background knowledge, reading proficiency, and math abilities that their students have acquired prior to taking their class. Teachers also use assessment to identify the learning and cognitive styles of each student in order to ascertain the best ways to deliver curriculum. Accomplished teachers regularly lay the foundation for each unit of study by assessing students' prior knowledge and identifying student preconceptions. (See [Standard I—Understanding Students](#).)

As learning progresses, accomplished science teachers use well-crafted assessments in a continuous process to determine student progress toward clearly defined learning goals. Teachers use the resulting data to modify instruction for the entire class as well as to differentiate instruction in response to the needs of specific students. Teachers understand that one purpose of formative assessment is to communicate with students and parents about progress towards learning goals, and another main purpose is to aid in reflection on the teacher's own practice and next steps in planning. Accomplished science teachers recognize that assessing in the moment allows teachers to make timely instructional adjustments.

Accomplished science teachers use assessments at culminating points in instruction, such as at the end of a unit of study or the end of a course, in order to determine the growth of students' knowledge, understandings, and skills in science and to place a value on students' progress. Accomplished teachers recognize the complexities of grading student performance and can justify the grades that they have assigned. Teachers realize that assessment tools alone cannot give a comprehensive picture of a student's learning experience. For example, a student's low grade on a final exam might not reflect the high level of understanding demonstrated through their classroom discourse. Additionally, a student who receives a high grade on a semester exam may not have made a full semester's worth of growth. Accomplished teachers also recognize that summative assessment tools can be used to evaluate their own practice relative to student learning.

Types of Assessment

Accomplished science teachers know that effective assessment tools vary in terms of their structure, format, duration, and complexity. They can range from simple recall tasks to probes of higher-order thinking. They can consist of multiple-choice or short-answer items designed to elicit specific facts, more open-ended assessments designed to test scientific reasoning, or performance exercises involving real-world tasks, such as designing and carrying out a scientific investigation to answer a research question derived from a community problem. Assessments may contain online components, including simulations. They can consist of teacher observations of students discussing concepts or engaging in experiments. Most assessments are carefully planned and implemented, but some are spontaneous, such as quick checks for student understanding in the middle of a lesson. Accomplished science teachers realize that a robust assessment plan consists of multiple assessments of different types. Teachers recognize that all student work should be purposeful and informative, leading the teacher to a complete picture of students' science understandings.

Accomplished science teachers are aware that mandated testing is an integral part of the assessment process. Accomplished teachers have a functional understanding of the process through which standardized tests are created and how validity and reliability are established. Teachers actively seek information on the underlying content standards and curriculum frameworks of these tests, and they use this information to inform instruction. When possible, accomplished science teachers use technology to analyze the data of mandated exams. Teachers use the results of mandated exams to draw comparisons between students and their peers or to determine whether or not students have learned specific science content and skills. Teachers realize that standardized testing may allow student progress to be monitored over the years; the data can help teachers know when specific kinds of support are necessary, both for groups of students and for individuals. Accomplished science teachers advocate for high-quality assessments that accurately reflect student learning on every level. To the extent possible, teachers participate in the processes of developing, reviewing, and scoring standardized assessments. (See [Standard VII—Advancing Professionalism](#).)

The Process of Assessment

Accomplished science teachers can successfully implement each step in the process of meaningful assessment. Teachers select and develop assessments according to the needs of their students, always ensuring that the assessment questions and activities are clearly aligned to defined learning goals. When administering assessments, accomplished science teachers make adjustments and accommodations according to students' needs. These teachers know how to interpret and utilize assessment results to improve instruction. They clearly and sensitively communicate assessment results to students, parents, and colleagues. Accomplished teachers realize that some assessments can have instructional value. For example, students preparing for a presentation on a particular topic may delve more deeply into the subject than they would have done otherwise. Alternatively, an assessment task might ask students to apply knowledge to a novel situation, and

this process could reinforce and deepen students' understanding of science. For example, after a lesson on circuits, students might be given additional materials such as batteries, lights, and switches with which to demonstrate their understanding of circuitry.

Selecting and Developing Assessments

Whether they devise assessments themselves or obtain them from some other source, accomplished science teachers can articulate specific purposes for every assessment they administer. Teachers choose assessments purposefully to gauge student progress towards learning targets.

Accomplished science teachers develop and select assessments based on clear criteria. Teachers work to ensure that assessments are clearly aligned with learning goals; and to minimize any bias that might distort assessment results. They choose and construct assessment tools that enable students to demonstrate what they know and can do; teachers ensure that the format, readability, duration, and complexity of the assessment are appropriate. Teachers make sure that each assessment they select or develop answers a significant question about student learning. When developing pre- and posttests, accomplished science teachers make sure that the tests are parallel in construction and coverage so that they actually assess increases in student knowledge rather than extraneous factors.

Accomplished science teachers differentiate assessments in response to the needs of specific learners while maintaining the integrity of the test. For example, an assessment might need to be translated into an ELL student's first language or presented orally for a student who has trouble reading. Some students might need to be allotted more time to take a timed test, while others might need help registering their responses. Accomplished teachers recognize the challenges involved in modifying the form of an assessment without distorting its purpose and validity. Accomplished teachers provide students with the resources they need to complete an assessment equitably; these may include but are not limited to vocabulary lists, word banks, translation dictionaries, and students' own science notebooks. At times, supplemental resources or modified testing conditions are not enough, and the accomplished teacher provides alternatives to the assessment tool itself. For example, a student who cannot excel on a multiple-choice test might be given the chance to demonstrate knowledge through an oral interview or by writing a narrative or creating a song. (See [Standard I—Understanding Students](#).)

Technology may assist an accomplished science teacher in finding and creating appropriate assessments. Digital tools provide access to a wide range of assessments, including simulations and digital modeling tools, practice opportunities, and review lessons. Technology can also be used to create, revise, and archive multiple forms of assessments. Accomplished teachers also use technology to collaborate with peers from learning communities to develop, deploy, and reflect on the results of common assessments. (See [Standard VII—Advancing Professionalism](#).)

Administering Assessments

Accomplished science teachers administer all assessments thoughtfully. They carefully prepare students by aligning assessments with learning goals and by being transparent about what students can expect in terms of the content and skills that will be assessed, the structure and scope of the assessment, and the way results will be interpreted and scored. Accomplished teachers ensure equity by allowing sufficient time for students to complete an assessment, ensuring that the test environment is conducive to student performance, and providing necessary accommodations. Teachers carefully consider such environmental factors as lighting, sound level, temperature, and time of day and adjust them for individual students to the extent possible. Accomplished teachers recognize that some students experience test anxiety and that others have been led to believe that they are members of groups that underperform on certain tasks. These factors can seriously distort students' ability to show what they know and can do related to science; therefore, accomplished teachers supply students with strategies and information for dealing with these problems. When it is appropriate to do so, teachers refer students to school professionals with the necessary expertise.

Accomplished science teachers collect evidence of student understanding in a variety of ways. In addition to administering traditional tests and quizzes, accomplished science teachers systematically monitor the quality of student contributions to group discussions. They observe scientific investigations to evaluate students' scientific reasoning, application of thought processes, and use of scientific tools. Accomplished teachers record their observations of student activities and performances in a thoughtful and systematic way. Teachers carefully register their observations of each student at regular intervals rather than making notations only when something unusual has happened.

Accomplished science teachers involve students in assessing their own progress because teachers realize that doing so fosters student reflection and the growth of independent learning. Accomplished teachers encourage students to set high goals for themselves and teach students how to evaluate their own progress toward these goals. Teachers provide students with a variety of tools, such as rubrics, scoring guides, rating scales, question sets, and think-alouds; they then give students multiple opportunities to use these tools in assessing their own progress. Teachers foster students' ability to think about what they know, how they know it, and the extent to which they demonstrate that knowledge. Furthermore, in circumstances when it is appropriate to do so, teachers involve students in designing assessments for the entire class. For example, teachers might encourage students to generate test questions or rubrics.

To the extent possible and appropriate, accomplished science teachers use technological tools to help them administer assessments. For example, teachers may use technology to administer quick assessments throughout a unit in order to make sure students are progressing towards meeting learning goals. A major advantage of using technology in this way is that both students and teachers receive immediate feedback. Accomplished science teachers also advocate for assistive technologies

so that students can have appropriate modifications to testing procedures, even if that modification is not part of a formal plan or IEP. (See [Standard VIII—Diversity, Fairness, Equity, and Ethics](#).)

Interpreting and Utilizing Assessment Results

Accomplished science teachers have the knowledge and skills required to interpret the results of assessments in terms of students' backgrounds, needs, and strengths. They also know how to apply assessment results, both to fine-tune instruction and to place fair valuations on student performance when necessary. Accomplished teachers pay attention to what results indicate about the performance and needs of individual students, and they also look for patterns that provide insights into the class as a whole. By collecting multiple sets of data over time, teachers can follow the progress of student thinking. When appropriate, teachers engage in the process of interpreting assessment results with colleagues or with students themselves.

Accomplished science teachers apply assessment results to modify instruction for individuals and to make large-scale adjustments in their teaching. For example, if a few students showed confusion about a given concept, a teacher might reteach the concept to just those students. However, if the class as a whole demonstrated a lack of understanding, an accomplished teacher would reassess the approach initially used to convey that concept and then radically readjust that lesson or unit to improve student understanding. Accomplished teachers do not interpret or apply the results of a given assessment in an isolated fashion; rather, they compare results on multiple assessments—including assessments from previous years and even other subjects—in order to create a rich, multidimensional picture of student learning. Accomplished science teachers believe that all students are capable of making meaningful gains in understanding science, and teachers know that these gains can be expressed in a number of ways. (See [Standard I—Understanding Students](#).)

Accomplished science teachers develop and provide to their students a clear assessment plan describing how student performance will be measured, recorded, reported, and interpreted. Teachers use assessment to determine where incomplete understandings may have occurred, and they reflect on these concerns and work with students to determine a course of action for improvement. For example, teachers may share a rubric with students at the beginning of the project, review the related product with students using the rubric once work has begun, and then give students opportunities to improve project work according to the dimensions elucidated in the rubric.

Accomplished science teachers conduct ongoing evaluations of their assessment tools. Teachers perceive when poor student performance on an assessment or part of an assessment indicates a flaw in the tool and when it indicates that students did not understand science concepts or develop certain skills. When the tool is faulty, accomplished teachers replace or revise it, and, whenever appropriate, reassess students using the new or improved assessment tool. Accomplished teachers make

every effort to make sure that students' results on every assessment accurately reflect student progress.

Communicating the Results of Assessment

Accomplished science teachers communicate the results of assessment clearly and sensitively to students, colleagues, and parents. Teachers provide regular reports that provide evidence about student progress toward clearly defined learning goals. Accomplished teachers ensure that stakeholders have a clear understanding of the connections between assessment criteria and the purposes of the lessons, projects, and student work being assessed. Accomplished teachers prepare evaluations of student progress that clearly communicate the kind and quality of gains in science knowledge and skills that students have been making and, when appropriate, the need for improvement.

Accomplished science teachers provide students with feedback that is informative, timely, and comprehensive; teachers explain what each result means, where students are doing well, and where they need to improve. Accomplished science teachers use constructive feedback to increase student learning and to address conceptual development. In the hands of an accomplished teacher, constructive feedback is specific and is designed to improve student performance, promote growth, and increase a student's self-worth. For example, feedback on a laboratory report would highlight the innovative and effective components, while providing specific details on how to improve aspects of the report. Accomplished teachers give their students an opportunity to discuss their perspective on the assessment and its results.

In order to capitalize on the potential partnership between teacher and home, accomplished science teachers attempt to establish a connection that facilitates ongoing, two-way communication. These teachers create progress reports and use multiple modes of communication to describe the kind of work each child is completing in science class. An accomplished teacher is aware of what language is spoken in the home, and any limitations, such as those related to technology or schedules. Accomplished science teachers make every effort to address obstacles to communication. For example, accomplished science teachers obtain translations where possible and appropriate, make phone calls and home visits instead of emails, and make time available beyond the school day. (See [Standard VI—Family and Community Partnerships](#).)

Accomplished science teachers share insights from assessments with colleagues—both those currently teaching the students in other subjects and those who will teach students science in the future. Accomplished teachers proactively help other teachers understand what their students know, understand, and can do. Furthermore, teachers share with colleagues and administrators what assessment results suggest about the success of the science program and the ways it might be improved. Thus, accomplished science teachers communicate assessment results in order to improve individual student learning and the science program as a whole. (See [Standard VII—Advancing Professionalism](#).)

Diversity, Fairness, Equity, and Ethics

Accomplished science teachers make every effort to ensure that the language used in assessments is clear and familiar to students and that tools assess what they intend to assess. These teachers understand that the context of the scientific information embedded in a test question or other type of assessment activity may unfairly impact a student's ability to demonstrate what he or she knows. For example, if a concept such as energy is tested in an item that refers to snowboards, students from warm climates might not be able to envision the example and would thus be unable to fairly demonstrate their understanding of the pertinent scientific knowledge. Accomplished teachers avoid or eliminate such bias. Alternatively, if a number of English language learners show a pattern of missing certain questions, an accomplished teacher would consult with ELL colleagues to determine if specific terminology or grammatical constructions are responsible for the confusion, and if so, how to phrase the questions more understandably. Teachers understand where minor adjustments are sufficient and when more extensive interventions or accommodations are necessary. They work closely with other school professionals to ensure equitable assessment for all students.

Accomplished science teachers vary the types of assessments they administer in order to ensure fairness. For example, a Pacific Islander might be allowed to “talk story” (a cultural verbalization explaining a natural phenomenon) to demonstrate his or her science knowledge, while another student might be given the opportunity convey the same knowledge through a poem, a physical model, or a song. Delivery methods can be adjusted to students' learning and cognitive styles as well as to their cultural backgrounds.

Accomplished science teachers differentiate between assessing knowledge and judging student behavior, and these teachers assess students strictly on their progress toward learning goals. Teachers do not allow a student's actions—whether positive or negative—to bias them toward raising or lowering grades that should reflect the student's knowledge of science. However, accomplished teachers are also aware that inappropriate behavior may indicate that the student does not have an understanding of the concept being addressed.

Accomplished science teachers are ethical with regard to selecting, developing, administering, interpreting, utilizing, and communicating assessment results. They are transparent with regard to how each assessment will be evaluated. Students are provided with guidelines prior to assessment. Accomplished teachers encourage peers to provide assessment feedback to each other, but they also ensure that the privacy of student performance is respected.

Reflective Practices

Accomplished teachers reflect on the extent to which their chosen or created assessment tools align with the learning goals and needs of their students. They see if each tool obtains the desired evidence and consider if there is a better means for

obtaining meaningful data. In the case of a disconnect between the assessment tool and what the teacher wants to measure, teachers ask themselves if the problem occurred because the teacher selected the wrong tool, the tool was inherently flawed, or the tool was administered incorrectly. Based on the conclusion, the accomplished teacher changes or modifies the assessment and re-administers it to students.

When administering an assessment, accomplished teachers consider whether every student has the optimal environment for demonstrating progress. Teachers observe the administration of the assessment and look for cues that students may be distracted, physically or emotionally uncomfortable, or unready. Teachers reflect to determine whether the administration of the assessment was mistimed by the teacher or whether the students' preparation for the assessment was at fault. Teachers may further discuss the circumstances with a student who had a bad experience to determine what steps need to be taken to provide a better assessment experience. Teachers reflect in action as well as after the fact. For example, while monitoring a class engaged in an assessment about how the body maintains temperature homeostasis, a teacher might notice that a few students are not writing. The teacher might interview these students. Upon realizing that the students do not understand the question, the teacher might rephrase it in terms of a familiar context.

When reflecting on whole-class or individual performance, teachers look for evidence of student learning and gaps in understanding so that they can provide additional support or other opportunities to further student growth. By examining multiple assessments over time, accomplished teachers gain a more comprehensive perspective of students' science understandings. Accomplished teachers reflect on trends in the aggregate and individual student performance in order to illuminate weaknesses in instruction and subsequently improve their teaching.

Accomplished teachers reflect on the clarity, effectiveness and timeliness of their communication regarding assessments and how well communication supports student growth. They seek ways to improve communication and clarify the connections between student results and learning goals. In seeking to foster two-way communication with students and their parents about assessment, accomplished teachers reflect on ways they can ground ongoing conversations in evidence of student learning. Teachers also reflect on the extent to which this communication impacts students' demonstrations of their understanding on subsequent assessments.

Accomplished teachers reflect to what extent each student has an equitable opportunity to have his or her understanding fairly assessed. Teachers are watchful for unexpected factors that could hinder student performance and make every effort to minimize such hindrances. Based on their reflections, accomplished teachers provide additional support or make accommodations to enable all students to demonstrate growth.

Standard V

Learning Environment

Accomplished science teachers create and maintain a safe and engaging learning environment to promote and support science learning for all students.

Introduction

Accomplished science teachers believe that a positive and productive environment supports high levels of science learning for all students. Therefore, accomplished teachers create an environment where students feel engaged in science and connected in productive ways to their teacher and peers. Students of accomplished teachers know what is expected of them and are confident and willing to participate because they perceive that their explorations in science are valuable.

Accomplished science teachers take responsibility for the physical, emotional, sociocultural, and intellectual aspects of the learning environment. They also consider learning environments beyond the classroom. These teachers recognize that the hallmarks of a positive and productive learning environment include safety, student engagement, fair and equitable opportunities, and deeply embedded science values. Accomplished teachers create an environment that helps students gain the sense that they belong to a science learning community and that nurtures in students the inherent curiosity about natural phenomena that is integral to the culture of science.

Safety

Although student safety is a priority in every science classroom, accomplished teachers are exemplary in their efforts to ensure safety for all students before, during, and after investigative activities. Accomplished teachers continuously teach and model proper laboratory procedures, including the appropriate use of materials and equipment. They scrupulously maintain safety equipment and teach their students how to use it. Teachers ensure that their students know emergency procedures, and teachers continually monitor their students' compliance with safety practices. Teachers ensure that all students and their guardians have signed safety contracts, and teachers use the contracts as an instructional and motivational tool in order to maintain a safe learning environment.

Accomplished science teachers realize that careful planning is crucial to safety and that safety considerations must be key when they are planning instruction. These teachers determine what laboratory activities are feasible based on students'

abilities and access to safety equipment. They ensure that the acquisition, storage, and disposal of chemicals and other materials meet all state and federal guidelines. They ensure that students dress and move appropriately in laboratory environments because they are intensely aware of the safety issues raised by the active nature and frequent transitions typical of a science classroom.

Accomplished science teachers realize that fostering a safe and inviting emotional climate is as important as ensuring students' physical safety. Teachers understand that establishing a safe emotional climate encourages students to take intellectual risks and allows them to become part of the culture of science. Accomplished teachers create and maintain a sense of community by encouraging students to show concern for others, demonstrating high expectations for all, involving all students in the practice of science, and dealing swiftly and constructively with inappropriate behavior, such as bullying. The resultant sense of community encourages students to more actively collaborate in the processes of science and to respect all ideas, familiar or not.

Accomplished science teachers lay the groundwork for emotional safety by involving students in setting behavioral expectations and boundaries. As a result, students are invested in the norms of the classroom. Problems are less likely to arise, and when they do occur, students are more likely to be a part of the solution. Teachers handle behavioral issues fairly and respectfully, de-escalating confrontations and minimizing disruptions to the learning process.

Accomplished science teachers realize that promoting respect and emotional safety is especially important when dealing with potentially sensitive topics in science. Teachers are aware of topics that may be distressing to individual students. For example, lessons on genetics need to take into account students with limited family information or a background of genetic disorders. Accomplished teachers model respectful and sensitive discussion questions and responses with students, ensuring the emotional safety of all students. For example, if an accomplished science teacher were to present a lesson on genetics, the teacher would model how to conduct the discussion in a respectful way. Creating a family tree can provide interesting links between the science of genetics and real life but may also raise unforeseen personal issues. Therefore, an accomplished teacher might provide a fictional case history from which students could design a family tree.

Accomplished science teachers understand that myriad opportunities for science learning exist outside the science laboratory. They encourage students to take advantage of varied learning experiences, but they are careful to research safety guidelines and prepare students before utilizing outside venues. Accomplished teachers model respect for nature, and they ensure that students venturing beyond the classroom are aware of possible dangers. Accomplished teachers realize that the need for safety in science extends to all outside learning activities, including outdoor lessons, field trips, or independent home projects; when it is appropriate to do so, teachers educate parents and other chaperones and advisors in safety concerns related to field trips or home learning. In addition, accomplished teachers verify that

adult chaperones assisting with field trips have appropriate backgrounds and are present in sufficient number to ensure the security of the students. Accomplished science teachers also teach students skills to ensure their safety while researching or discussing science in digital or virtual spaces.

Engagement

Accomplished science teachers structure the physical environment of the classroom in such a way as to establish an engaging atmosphere. They provide exciting materials that students will be motivated to explore, and authentic materials that will help students experience the culture of science. Materials may include displays, technological devices, print materials, models, laboratory equipment, and other elements that will appeal to students. (See [Standard 1—Understanding Students](#).)

In order to maximize student learning and engagement, accomplished science teachers modify various aspects of the physical environment, including lighting, seating arrangements, traffic patterns, and the location of materials. Teachers pay special attention to how modifications in the physical environment can promote flexible student grouping. For example, on one day an accomplished teacher might arrange the desks in a circle for Socratic discourse and then the next day might arrange the desks in small groups for collaborative work. Accomplished science teachers involve students in organizing the classroom in order to create a student-centered space. If there are significant obstacles to teachers' ability to control the physical environment, accomplished teachers are persistent in finding creative solutions to overcoming these barriers.

Accomplished science teachers utilize time effectively in order to maximize student learning. Teachers convey the importance of time management to their students. They establish patterns and routines that are orderly and effective to maximize student time on task. They teach students to apply efficiency to such classroom routines as procuring materials for lab experiments, managing laboratory notebooks, and submitting assignments.

Accomplished science teachers establish a productive social and emotional environment by demonstrating that they are committed to the belief that all students can learn and enjoy science. Accomplished teachers use techniques and methods that facilitate the academic performance of students from diverse racial, ethnic, and socioeconomic groups. Teachers are able to uncover the potential disconnects between school and home culture, and they make corresponding adjustments to the learning environment. Accomplished teachers recognize that there is a need to support all student groups, especially the underserved. An accomplished teacher would consider same-gender groupings for a lab activity that in past years had been dominated by one gender or another. For example, same-gender grouping might better allow for equitable participation from males and females in a lab activity using toy cars.

Accomplished science teachers strive to build a cooperative classroom community. These teachers know that adolescents are social creatures, so teachers promote their students' engagement by promoting collaborative learning. Teachers help students appreciate science as an opportunity to interact meaningfully with their peers, and teachers build on this enjoyment to promote students' engagement with science content and the process of inquiry. Teachers assign open-ended tasks that require students to pay attention to the dynamics of their interactions with others. Accomplished science teachers know that some aspects of student engagement are dependent upon the social and emotional development of the students and that developmental stages can vary among students of the same age. (See [Standard I—Understanding Students](#).)

Accomplished science teachers establish an intellectually stimulating environment that promotes engagement. They provide multiple avenues for learning that create a meaningful inquiry experience. These include learning activities that allow students multiple paths to understanding science concepts in the curriculum. Teachers encourage students to take intellectual risks. (See [Standard III—Curriculum and Instruction](#).)

Accomplished science teachers consistently communicate high expectations for all students because they know that doing so creates a healthy self-concept in their students, builds intrinsic motivation, and creates an environment of success. When students experience challenges, teachers never lower their expectations; rather they help all students rise to meet the standards. Students are empowered to take charge of their own learning and to work on research projects and assignments that are culturally and socially important to them.

Accomplished science teachers find ways to engage students through real-world connections. These may be via field trips, professionals invited into the classroom, or internships or shadowing programs. In addition, accomplished teachers make every effort to include role models and mentors from a variety of cultural backgrounds. Accomplished teachers help students realize that they can pursue science by exploring nature, taking field trips, conducting approved research at home, and learning online. For example, when studying cell biology, students could visit a local medical laboratory or could use a simulated cell tutorial at home. Both of these opportunities extend the boundaries of the classroom and encourage students to think about science as more than a school subject. (See [Standard VI—Family and Community Partnerships](#).)

Diversity, Fairness, Equity, and Ethics

The classrooms of accomplished science teachers are accessible to all students regardless of physical, intellectual, religious, or other characteristics. Teachers ensure that students with exceptional needs have equitable access to supplies and materials in order to participate fully in the curriculum. Accomplished teachers provide equitable access to learning activities for all students, making necessary accommodations but ensuring that all students can participate in the social and intellectual dynamics of the

classroom. For example, a student with severe visual limitations might be provided with access to a dynamic computer simulation to observe cell structures, or a student who is unable to take a pulse manually could be given a digital data collector. Accomplished teachers are also proactive with students who have allergies, taking every precaution to maintain their safety. Whenever they make accommodations for students, accomplished teachers make special efforts to keep these students from feeling isolated or excluded.

Accomplished science teachers consider diversity, fairness, equity, and ethics when they are establishing and maintaining the intellectual environment. Accomplished teachers demonstrate respect for students' background knowledge and experiences. They use relevant examples and data from a variety of cultures and groups to illustrate key concepts and enhance opportunities for learning. For example, during a lesson on food webs, out of respect for the heritage of Native American students, a teacher might explain how awareness of the lurking or hiding behavior of coyotes was incorporated into Navajo mythology by presenting the coyote as a powerful and cunning trickster—a cultural hero. Teachers know that addressing the needs of a diverse classroom is an ongoing process that requires careful attention and continued effort.

Reflective Practices

Accomplished science teachers understand that reflecting about the learning environment is an important professional responsibility. Teachers reflect on the degree to which the learning environment promotes physical, emotional, and intellectual safety. They use reflection to assess how the classroom environment either fosters or impedes student engagement. Accomplished teachers reflect on how they can improve the capacity of the learning environment to support all students equitably.

Accomplished science teachers examine and reflect on interactions among students, the classroom, and materials to determine areas where the physical safety of their classroom can be improved. For example, if students are working too closely together to use a Bunsen burner safely, the teacher makes appropriate adjustments to the classroom setup. Accomplished teachers also enhance intellectual and emotional safety by determining if all students are modeling respect and if instruction on appropriate interactions is provided when needed. By paying attention to how and when students contribute to classroom discourse, teachers gauge the level of intellectual safety in the learning environment. They then make adjustments to encourage the respectful exchange of ideas when needed.

Accomplished science teachers recognize that it is critical to determine that every student is engaged in the lesson. Building the habit of reflective practice allows teachers to remain focused in the dynamic environment of the classroom and to collect evidence of student engagement in the moment. Teachers observe students' facial expressions and body language to measure enthusiasm, optimism, and curiosity for the learning experience. They determine if their students are interested based on whether or not students initiate productive actions and show sustained

involvement in the learning activities. Teachers also reflect on assessment results for evidence of student engagement. If student engagement is lacking, accomplished teachers reflect on possible ways to alter classroom practices to better sustain student interest.

Engaging in reflection helps accomplished science teachers recognize personal biases that can impede their ability to provide a safe and engaging learning environment. When biases are identified, accomplished teachers alter their practice so that every student has opportunities to participate meaningfully in learning activities. Open-minded teachers continually seek new information that might challenge their assumptions about teaching and about students, thus allowing them to envision new ways to increase access for all students.

Standard VI

Family and Community Partnerships

Accomplished science teachers establish productive interactions and successful partnerships with families and communities to enhance student learning.

Introduction

Accomplished science teachers understand that interactions and partnerships with families, community members, and other stakeholders are critical to the mission of teaching science. Teachers realize that it is their responsibility to ensure that all of these interactions are focused on students' best interests, and they also understand that the contexts in which they teach help to determine the kinds of relationships they need to establish.

When establishing partnerships, accomplished science teachers tailor their efforts to the developmental level of their students, the type of curriculum they teach, the nature of the school, and the community they work in. Teachers are diligent and creative, overcoming challenges to communication and collaboration. Accomplished teachers understand that interactions and partnerships should not exist merely for the sake of existing. Partnerships must be deliberate and purposeful, and those who collaborate must do so with the goal of benefitting students in clear and definite ways. Accomplished teachers see their students' families and the community as an extension of the school, and teachers take advantage of local resources to bolster the curriculum and foster student learning.

Partnerships with Families

Accomplished science teachers involve families in thoughtful and productive ways, creating partnerships that are ongoing, consistent, and constructive. Teachers realize that the expectations and actions of families have a huge impact on the educational success of students. Teachers respect the fact that parents can often provide valuable insights into the effectiveness of various instructional approaches with particular students. Teachers acknowledge that all parents have high aspirations for their children and that these aspirations may differ from teacher aspirations. For example, a science teacher might aspire for his or her students to attend institutes of higher education and pursue careers in science and technology, whereas a parent with a tradition of lobstering might not want his or her children to pursue postsecondary

education but might highly value their ability to apply science understandings in order to become successful businesspeople, navigators, and stewards of the ecosystem. Accomplished teachers demonstrate respect for all families and work toward common goals for the students. (See [Standard I—Understanding Students](#) and [Standard V—Learning Environment](#).)

Accomplished science teachers actively approach students' families. Teachers make it clear that they envision school-family communication as a two-way street; teachers venture into the community as well as inviting families into the school. Early in the academic year, teachers solicit the support of parents and other adult caregivers for the science program. Teachers are receptive and welcoming in their attitude; they seek information from parents and guardians about children's strengths, interests, preferences, learning goals, and home lives. They also anticipate parents' concerns. Teachers employ a variety of communication tools, including telephone calls, emails, and social networking tools in order to include as many families as possible. Accomplished teachers are sensitive to the fact that for cultural and personal reasons, some families may not welcome interaction with teachers.

Accomplished science teachers provide information to families about the school science program's learning goals, content, instructional and assessment practices, expectations, and opportunities. They suggest actions that families can take to help students' growth in science understanding. For example, a teacher might point out that families can be helpful by providing a quiet place and a set time for homework and encouraging their students to observe and analyze everyday natural phenomena. From time to time, accomplished teachers may design an intriguing science activity with an eye toward involving the whole family.

Accomplished science teachers encourage parents and guardians to stay involved throughout the school year, and they give parents opportunities to do so. This approach may solidify the teacher-parent-student partnership. Accomplished teachers further this partnership in many ways. Parents and guardians are invited into the classroom during school and after school to participate in science activities. Accomplished teachers organize opportunities for families to volunteer to support the school and students. Accomplished teachers make efforts to schedule events at different times of the day and on different days of the week in order to help families who have complex, busy schedules become part of the school community.

Accomplished science teachers actively seek ways to disseminate information about the science program by learning what methods work most effectively in their community. Accomplished teachers might partner with media outlets and invite them to report on school science activities. Teachers encourage parents and guardians to participate in discourse about science education.

Accomplished science teachers and family members partner to help students become aware of the career opportunities that exist in science and science-related fields. Teachers and parents can work together to identify the many fields that are connected to science, such as agriculture, nursing, welding, plumbing, cosmetology,

electric utility construction and maintenance, and medical and laboratory technology. Family-teacher partnerships can reveal the many ways in which science impacts daily life in areas such as nutrition, health, gardening, lighting, and heating costs.

Partnerships with the Community

Accomplished science teachers forge productive relationships with a variety of community entities, leaders, and organizations. Accomplished science teachers realize that the concept of community is complex. A community may refer to a physical location or to a group of people who identify with each other. Some students and teachers may live in neighborhoods close to the school and identify with a single political and cultural entity associated with one place. Other students may live in neighborhoods distant from a county or regional school. Some students may identify with communities of faith; immigrant communities; the lesbian, gay, bisexual, and transgender community; or other self-identified groups. Different layers and types of communities intersect and sometimes have opposing values, and accomplished teachers address multiple aspects of community interaction in their practice.

Accomplished science teachers educate local businesses and community groups about the science program. They draw on the expertise of local scientists and of those who apply scientific knowledge in their professions, such as plumbers, painters, horticulturalists, farmers, and veterinarians. They encourage students to communicate about science with their neighbors, employers, or government representatives. When possible, accomplished teachers encourage and create opportunities for students to show science relevancy to everyday experiences within the community. For example, teachers and students might organize a meeting to encourage or publicize recycling opportunities or the storage and disposal of toxic waste in the community, remaining sensitive to community attitudes in relation to these issues. Alternatively, students might help analyze the quality of a local stream or might count buds or butterflies to monitor local populations. Teachers understand that participating in such activities can enhance students' sense of connection to their community.

Accomplished science teachers realize that having students interact with members of the scientific community—whether face-to-face or virtually—can be a powerful educational tool. Students who do so can develop a greater understanding of the nature of science, develop deeper scientific understandings, and see the parallels between what they do in the classroom and what professional scientists do in their working lives. Students can become more aware of postsecondary and career opportunities available to them, and members of traditionally underrepresented populations in the field of science can interact with role models from varied backgrounds. Students can also perceive that scientists have both social and personal lives.

Accomplished science teachers identify and partner with businesses (including agricultural, industrial, manufacturing, and medical facilities), individuals with scientific expertise, organizations such as the local branch of an engineering association or a community service organization, and institutions such as zoos and museums. These

partnerships can fund science learning, provide instructional resources, and give students opportunities to connect with communities. Regardless of whether their schools are located in rural areas, small towns, or large cities, accomplished science teachers seek available partnerships.

When it is possible and appropriate to do so, accomplished science teachers connect their students to science departments of colleges and universities. Teachers identify higher education partners, including scientists and science educators. Teachers might arrange for these academic professionals to visit the classroom, share materials with students, or perhaps even involve students in their research. If such face-to-face involvement is not possible or practical, teachers might establish online communication between students and faculty. Teachers understand that forging these types of personal connections can be mutually beneficial. Students can visualize themselves as capable of participating in science and can expand their understandings and skills. Academic professionals can sometimes benefit from having students contribute to their research. For example, students could gather weather data using satellite imagery and provide that feedback to an academic partner.

As global communication becomes more available, accomplished science teachers realize how this resource can connect students to engaging learning opportunities beyond their immediate context. Teachers use a variety of low- and high-technology communication systems to connect their students with other science students, scientists, science professionals, science educators, and other people whose experiences or circumstances can reveal important issues related to science. For example, students might communicate with scientists who are conducting research on the rainforest canopy.

Accomplished science teachers know that it is very empowering when students who have spent many years in a school system can demonstrate what they have learned to others. A teacher might establish a program in which older students teach younger students what they know about natural phenomena in order to foster the interest of the younger students. High school and middle school students might showcase science projects to the community during an open house. Finally, an accomplished teacher might organize summer enrichment programs for students from the community in order to instill a passion for science and to provide an opportunity for scientific explorations.

Accomplished science teachers are conscious of their membership in the community. They are aware of their obligation to give back to the community and to foster in their students a similar sense of responsibility. Teachers encourage their students to actively participate in the world beyond the classroom and help them find appropriate ways to help their neighbors. Accomplished teachers set an example of community participation and involve their students in science-related activities that have an altruistic motive—for example, volunteering at a regional hospital to help in the blood testing laboratory or interning at the local Environmental Protection Administration office to help measure pollen counts.

Diversity, Fairness, Equity and Ethics

Accomplished science teachers seek diverse community partnerships. One reason they do so is to help students perceive that science is contributed to and practiced in all cultures and by many types of people—both those who resemble the students and those who are very different.

Accomplished teachers are aware that the diversity and complexity of families affect students' academic performance. As appropriate, accomplished teachers familiarize themselves with students' backgrounds and obtain information through various sources. Accomplished teachers gain additional knowledge about diverse cultures from community representatives or additional sources of information. Accomplished teachers use this information to develop and strengthen their partnerships to enhance student learning. (See [Standard I—Understanding Students](#), [Standard V—Learning Environment](#), and [Standard VII—Advancing Professionalism](#).)

Accomplished teachers treat families with sensitivity, respect, and understanding, realizing that families' prior experiences with school often frame their expectations and attitudes. Teachers create opportunities for science learning for families through thoughtful communication.

Timely response and active outreach are hallmarks of accomplished science teachers' communication with families, regardless of any sociocultural disconnects that may exist, such as language issues. When families do not speak English, teachers make every effort to have materials translated into the families' first languages, or teachers communicate through a translator. When families cannot read, teachers arrange for a meeting at the school or a home visit to communicate important information orally, if this is possible. If the school lacks the resources to make the desired translations, accomplished teachers are resourceful in conveying the essence of their messages, for example by using pictures.

Accomplished teachers understand that community partnerships expand student understanding and the learning of science. Teachers make a conscious effort to ensure that all students are given equitable opportunities to participate in activities such as internships, and they carefully match students and partners.

Accomplished science teachers respect the need for ethical and professional behavior. Science teachers use personal information about students, such as their medical history, for professional reasons, such as ensuring student safety in the science laboratory. At the same time, teachers take proactive measures to ensure the confidentiality of such information. Accomplished science teachers take care to obtain parental permission for activities outside of normal classroom routines. Accomplished teachers take sociocultural factors into consideration when planning science partnerships and community interactions for students.

Before establishing research partnerships between the school and the community, accomplished science teachers present lessons addressing the ethical guidelines

that students must observe. In addition, teachers screen all information that students will receive and activities that they will be involved in for age-appropriateness and sociocultural suitability.

Reflective Practices

Accomplished science teachers reflect on the process of establishing partnerships with families and on the ways these partnerships strengthen the relationship between home and school. Teachers are mindful that these interactions take time to develop, and they are vigilant about keeping track of what they have done to move the process forward. Through reflection, teachers recognize successful methods of partnering and consider how they can expand their efforts. They also consider situations that have not met with success and contemplate alternatives.

Accomplished science teachers reflect on ways they can involve their students with the community in order to provide authentic, real-world experiences with science. Teachers realize that they need to spend a lot of time and effort recruiting outside community members. Accomplished teachers analyze all of the community connections they have made in the past and consider ways to foster those partnerships in the future.

Accomplished science teachers reflect to ensure that they have established relationships with professionals in science that represent a wide diversity of cultures, genders, and backgrounds. They continually think about ways to inspire students to see themselves in scientific careers, and they reflect on additional opportunities that might better connect all students with the scientific community.

Accomplished science teachers reflect upon their students' interests when advocating for partnerships within the community. Teachers also reflect on whether these partnerships are the best fit for each student, considering ways to meet the students' interests or needs. They reflect upon community resources and are vigilant in using those resources to enhance student learning.

Accomplished science teachers find ways to involve their students in reflecting on how community interactions and partnerships can benefit students. Methods for obtaining this information include interest inventories, intentional classroom conversations, and journaling. Teachers seek input and insights from their students to better focus these partnerships on students' needs. Accomplished science teachers also find ways to involve community partners in reflecting on how community interactions and partnerships benefit student learning. Accomplished teachers continually reflect on ways to improve the process of identifying new partnerships and strengthening existing ones.

Accomplished teachers reflect on how they consistently address diversity, fairness, equity, and ethics when establishing interactions and partnerships. Teachers also reflect on how student engagement and learning may be enhanced when community partnerships incorporate a high degree of diversity. Accomplished

teachers continually reflect on ways to better serve all student populations by better incorporating diversity, fairness, equity, and ethics throughout all school-family and school-community partnerships.

Standard VII

Advancing Professionalism

Accomplished science teachers advance their professionalism by pursuing leadership roles, collaborating with colleagues, and undertaking high-quality professional learning opportunities.

Accomplished science teachers advance their professionalism on multiple fronts. They actively demonstrate leadership within their schools and beyond, making positive contributions to science education. Accomplished science teachers collaborate with colleagues, families, and stakeholders in order to enhance student learning experiences.

Accomplished science teachers are active members of learning communities. 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. Accomplished teachers value collaboration among professional stakeholders because it leads to opportunities to advance student learning.

Accomplished science teachers improve their expertise by engaging in professional learning opportunities for continuous improvement of their practice. Teachers realize that effective professional learning has a positive, lasting impact on teaching and learning.

In the eyes of accomplished teachers, all actions related to collaboration, leadership, and professional learning must be focused on one ultimate purpose: improving student learning. Therefore, these teachers continuously reflect on the degree to which their professional actions achieve this goal.

Leadership

Accomplished science teachers pursue leadership roles in order to share their science teaching expertise and to provide direction and inspiration to others. Accomplished teachers seek a range of such roles, from serving in appointed or elected positions and joining committees to leading in less formal ways such as initiating discourse with colleagues or planning lessons with other teachers. Accomplished teachers address issues and situations within their school community and beyond, and they are willing to take risks and make decisions.

Accomplished science teachers influence others by being agents of change, by promoting an elevated vision of science education, and by serving as model teachers for colleagues. Accomplished teachers seek input from key stakeholders, including students, colleagues, administrators, parents, and community members to ensure that all decisions promote high-quality teaching and improved student learning.

Accomplished science teachers believe that teaching is a worthy endeavor, and they promote the vision of teaching as a profession. They help build a community of educators, and they advance an atmosphere of intellectualism within that community. Whenever possible, accomplished teachers observe and hold constructive conversations with colleagues about instructional approaches. They may share successful practices, organize workshops, or publish in journals. They may organize informal study groups to discuss important topics and research papers. They may read and post to online discussion groups and subscribe to electronic mailing lists in their subject area. They play an active part in, and make a positive contribution to, professional organizations, and may serve on educational task forces, committees, or boards.

Accomplished science teachers advance the knowledge and practice of colleagues in several other ways as well. For example, they may design and carry out professional learning activities in science, including mentoring preservice and novice teachers and others who may have limited science backgrounds or who are searching for new ways to enrich their own teaching. Accomplished teachers may advocate for securing and implementing resources and may make their colleagues aware of new uses of technology. Accomplished teachers take the lead in advocating for the improvement of instructional materials; for example, they may suggest ways to incorporate the latest science and science education research into student resources.

Accomplished science teachers do not confine their leadership role to the areas of instruction and best practice. They work with colleagues and other specialists to take action in promoting fairness and equity for all members of the learning community, including students with exceptionalities and English language learners. Teachers promote and lead discussions of diversity issues and model ethical behavior; for example, they initiate discussions with colleagues to uncover issues of inequity in their school. Accomplished teachers take targeted action to provide and enhance high-quality science education for underserved students and students from underrepresented populations. (See [Standard VIII—Diversity, Fairness, Equity, and Ethics](#).)

Professional Collaboration

Accomplished science teachers understand the importance of being active members of learning communities. These teachers seek ways to collaborate with other educators to improve student learning and their own teaching practices. Teachers join various types of collaborative learning groups; these groups may extend beyond the local community to state, national, and international levels. Accomplished

science teachers use collaboration to analyze and improve instructional strategies and assessment practices. Their methods include but are not limited to gathering data via lesson study, videotaping, or classroom observations, and engaging in dialogue to evaluate these data.

Accomplished science teachers use collaboration to strengthen their schools. They participate in the solution of schoolwide and districtwide problems. They may contribute to discussions of policy, especially those related to K–12 science, in ways that demonstrate professional responsibility and advocacy for the well-being of their students.

Accomplished science teachers collaborate regularly with professional colleagues other than science educators. They work with special educators, speech therapists, school counselors, teachers of English language learners, occupational therapists, physical therapists, school psychologists, school nurses, administrators, educational aides or paraeducators, library media specialists, coaches, office staff, resource officers, professional educational consultants, and support staff. Accomplished teachers pursue a wealth of school partnerships in order to share perspectives, information, and resources to enhance students' learning and well-being.

Accomplished science teachers may collaborate with researchers, scientists, or postsecondary educators to further enhance their content and pedagogical content knowledge or to provide meaningful learning experiences for their students. Accomplished teachers share the benefits of these collaborations with their fellow teachers. For example, collaborations with institutions of higher education can enhance science teachers' awareness of science-related careers and postsecondary opportunities in technology, engineering, and related fields. As a result, teachers gain the ability to discuss applications of science and engineering practices with their students. Accomplished teachers may co-teach science education courses with faculty at institutions of higher education. (See [Standard VI—Family and Community Partnerships](#).)

Professional Learning

Accomplished science teachers recognize that ongoing professional learning is an effective method for enhancing teaching expertise, and thus they seek opportunities for themselves and others to engage in professional learning. Accomplished teachers realize that professional learning is not limited to attending district-provided workshops and seminars; it may include attending free webinars, reading professional publications, joining online discussion groups, or observing other teachers. Accomplished teachers understand that the science content and pedagogical knowledge and skills acquired during professional learning activities must be carefully incorporated into instructional practices and refined by feedback and reflection.

Accomplished teachers also share what they have learned with their colleagues. When appropriate, accomplished science teachers may suggest ideas for professional

learning activities to those responsible for establishing such initiatives at the district, state, or national level. For example, a teacher returning from a national conference might request a districtwide professional workshop on one of the topics that was covered. Accomplished teachers make an effort to sustain the new understandings and skills generated through professional learning.

Accomplished science teachers carefully select the professional learning options that will best equip them to increase their competencies and address the specific learning needs of their students. Accomplished teachers also realize that even in areas where they are knowledgeable and confident, professional learning may offer new insights, productively challenge old ideas and practices, and move them toward a higher level of expertise. Accomplished science teachers place a priority on professional learning activities that can be integrated and coordinated with other school initiatives and embedded into curriculum, instruction, and assessment practices. They seek out activities that concentrate on science content and pedagogy and that are derived from research and exemplary practice.

Reflective Practices

Accomplished science teachers actively reflect on leadership, collaboration, and professional learning in order to improve their professional practices. Accomplished teachers reflect on their practice in order to clearly articulate to students, other practitioners, administrators, families, and the community at large the value of science education and the forms it must take if all students are to become science-literate adults.

Accomplished science teachers reflect on their formal leadership roles and how well they are meeting the responsibilities of a leader. In addition, they reflect on their work and try to discover what further actions they must take in order to be more effective in formal leadership roles. Accomplished teachers reflect on the extent and the effectiveness of their informal leadership efforts. These reflections may lead teachers to request the assistance of colleagues. Accomplished teachers reflect on their advocacy efforts to determine if these efforts are leading to sustainable programs, instructional activities, and resources that promote professional learning and student learning.

Accomplished science teachers reflect on their collaborative roles and how the act of collaborating advances the knowledge and practices of themselves and their colleagues. Through honest and rigorous reflection within collaborative groups, teachers carefully examine their own and others' practices in order to strengthen the quality and effectiveness of teaching. Accomplished teachers attend to those attributes that lead to group cohesiveness; for example, teachers assess how skillfully they insert themselves in the group and whether or not they listen actively and respond honestly to others. If they identify weaknesses in their approaches, they reflect on ways to improve their interactions. Accomplished teachers assess whether their relationships with nonscience building staff are professional and respectful and make any necessary adjustments. Accomplished teachers recognize

the needs of the new science teachers they mentor—both formally and informally—and they reflect on how well they recognize new teachers' needs and respond to those needs in a timely, professional, and respectful manner. Accomplished teachers also evaluate the scope and effectiveness of their collaborations beyond the school. Finally, accomplished teachers reflect on how well they sustain all of their collaborative efforts by determining if their professional goals have been met.

Accomplished science teachers actively reflect on their beliefs about teaching and learning and about their own teaching practice in order to select appropriate professional learning opportunities. Teachers use reflection to determine whether professional learning opportunities have a strong potential to aid students, and they evaluate opportunities through the lenses of fairness and equity. After engaging in professional learning experiences, teachers reflect on how best to sustain the insights they have derived and how to share relevant insights and materials with colleagues. Accomplished science teachers continually reflect on how to identify and take advantage of future learning opportunities in order to advance their knowledge and instructional practices.

Standard VIII

Diversity, Fairness, Equity, and Ethics

Accomplished science teachers understand and value diversity, and they engage all students in high-quality science learning through fair, equitable, and ethical teaching practices.

Introduction

Accomplished science teachers believe that all students can develop conceptual understandings about science and can engage in scientific inquiry. Teachers act on this belief by ensuring that each student has equitable access to an empowering science education. Accomplished teachers respond sensitively to human differences and build on individual strengths.

Accomplished science teachers understand and value the diversity of their students. Accomplished teachers value each student's cultural, linguistic, religious, regional, and ethnic heritage; family configuration; socioeconomic status; sexual identity; gender; body image; physical and cognitive exceptionalities; prior learning or literacy experiences; learning style; and personal interests, needs, and goals. By valuing diversity, teachers model and teach respect for all people and groups. Teachers use their knowledge of diverse cultures and contexts combined with their knowledge of students to improve student understanding of science. Accomplished teachers are aware of their own beliefs and take them into consideration when designing instruction.

Accomplished teachers understand the wide range of exceptionalities that can exist within a classroom. Exceptionalities include identified and unidentified learning needs, as well as gifted abilities. Accomplished teachers realize that every student's profile is unique. Many students have special needs in some areas and talents in others. Teachers hold all students to high standards regardless of their abilities. They realize that all students need science instruction that is exciting, challenging, engaging, and appropriate.

Accomplished science teachers understand that the way to achieve fairness is not to teach each student in exactly the same manner, but rather to teach every student equitably. Equity in the classroom means that teachers ensure that all students have the type and level of support they need and an instructional setting that promotes rigorous learning. Fairness refers to the intentional efforts of a teacher

to act justly and impartially to establish a positive learning experience for each student. Accomplished teachers understand their obligation to provide curriculum, instruction, assessment, and a learning environment conducive to the success of all students. For example, accomplished teachers recognize that some groups have historically been excluded from science. Accomplished teachers make every effort to help students from underrepresented groups actualize their potential in the science classroom and in science-related careers. Accomplished teachers may recruit students from underrepresented groups to enroll in advanced-level science courses or gifted programs.

Accomplished science teachers model ethical behavior in every aspect of their teaching. They behave with responsibility and integrity with regard to all professional interactions. They demonstrate their ethical behavior by providing a fair and equitable science education for all students. Through their actions, they respect and value all students. Accomplished teachers demonstrate intellectual ethics in any research they conduct and in any materials they publish; show respect and honesty in regard to colleagues, administrators, and community stakeholders; and uphold a high standard of ethics in all professional responsibilities.

Valuing Diversity

Accomplished science teachers value the diversity of their students, of all those who have contributed to scientific knowledge, and of the world at large. By honoring and valuing diversity, accomplished teachers model respect for all individuals and groups. Teachers believe that both differences and commonalities among students are sources of strength for the learning community, and they express this belief to their students. Through their relationships with students, teachers address the issue of diversity by creating an environment where students are known, understood, and embraced for who they are.

Accomplished science teachers believe fervently that diversity enriches the learning environment by providing varied contexts for understanding science. Teachers value the background knowledge, culture, experiences, history, and identity students bring to the classroom, and teachers leverage these personal resources to improve science learning. For example, in a unit on health issues, an accomplished teacher might discuss the traditional uses of medicinal plants in order to demonstrate the scientific practices of a particular culture and connect those understandings to current health issues in the community.

Accomplished science teachers inform themselves about how the specific backgrounds of their students can impact students' science learning and their education in general. Teachers' actions range from being thoughtful about conditions and neighborhoods in their own community to actively researching the home countries of students who are recent immigrants and learning about relevant issues, beliefs, and world views in those countries. For example, teachers might learn how views on gender roles, authority, and home and academic responsibilities affect science

learning. (See [Standard I—Understanding Students](#) and [Standard III—Curriculum and Instruction](#).)

Accomplished science teachers believe that valuing diversity involves recognizing and respecting differences. These teachers realize that their first impressions of their students may be inaccurate and are inevitably incomplete; teachers make the effort to uncover relevant characteristics that make their students unique. Accomplished teachers recognize that their own cultural connections inform their teaching just as students' connections inform their learning. Teachers make a space for students to feel included by creating an atmosphere of trust and mutual respect. (See [Standard I—Understanding Students](#) and [Standard V—Learning Environment](#).)

Accomplished science teachers recognize that diversity exists in every classroom because each student has unique background characteristics, strengths, and needs. Accomplished teachers proactively learn about the characteristics that differentiate their students, including exceptional needs. However, teachers also see each student as an integral part of the classroom and believe that it is the teacher's job to create a fully inclusive and productive team. To achieve this goal, accomplished teachers are tireless in pursuing the productive contribution of every student. For example, a teacher who has students with a wide range of science knowledge and skills could tap into varying strengths to support all students' success in completion of a scientific investigation.

Accomplished science teachers make efforts to support diversity beyond the confines of their classrooms. They respect the diversity of their colleagues and coworkers. They value the work, ideas, and opinions of the other adults involved in the education of their students. They advocate in their communities for equitable practices based on diversity principles. They advocate for the representation of diverse communities in committees, student clubs, and organizations and for diversity in educational materials.

Promoting Fairness and Equity in the Science Classroom

Accomplished science teachers embody the belief that every child can succeed in science. They do not make assumptions that certain individuals or groups will fail. Accomplished teachers are unwavering in helping all students meet learning goals. Teachers set appropriate expectations and develop needed interventions based on a detailed knowledge of their students.

In order to promote fairness, accomplished science teachers involve students in the classroom decisions that most directly affect their learning. Teachers understand that allowing students to have a voice in their education is a powerful strategy for enhancing student engagement. Teachers create an equitable environment where all students make valuable contributions to the classroom, and where teachers and students co-navigate the learning process. (See [Standard III—Curriculum and Instruction](#) and [Standard V—Learning Environment](#).)

By making explicit their respect for every student in the classroom, accomplished science teachers encourage their students to behave respectfully toward others. Accomplished teachers create a classroom environment that encourages and accepts the diverse perspectives that all students bring to the classroom, including students whose opinions dissent from those of their classmates. Teachers encourage students to engage in productive discourse about the diverse claims that various individuals make from the same evidence. (See [Standard II—Knowledge of Science](#) and [Standard V—Learning Environment](#).)

Accomplished science teachers advocate for the learning needs of all students, including those with exceptionalities—whether identified or unidentified. For example, if a teacher has a student who has not been identified with a learning disability but has difficulty organizing science content in meaningful ways, the teacher—working in collaboration with colleagues—might show the student several organizing strategies for mapping connections among scientific concepts. Alternatively, if an accomplished teacher suspects that a given student has been misidentified as having exceptionalities, the teacher would advocate for a reevaluation.

Ethics in Science Teaching and Learning

Accomplished science teachers teach with competence, act with integrity, treat all students with dignity and respect, provide professional support for colleagues and communities, comply with relevant laws and regulations, and advocate for improvements in their school and profession when it is appropriate to do so. Teachers conduct relationships with students, families, and colleagues in a professional manner that elevates the regard for teaching and increases respect for the field of science.

Accomplished science teachers do what is best for their students' learning. They recognize the magnitude of their responsibility, knowing that all of their actions have the potential to impact their students. Teachers believe that they can make significant, positive contributions to students' lives, and they do everything in their power to avoid causing any harm. For example, accomplished teachers always refer to their students in positive ways, whether in the classroom or in the faculty room.

Accomplished science teachers realize that when teaching about ethical dilemmas in science, they need to be aware of the complex contexts in which students view these dilemmas. Accomplished teachers recognize that when discussing controversial science issues, such as climate change or air quality, it is their responsibility to keep their teaching deeply rooted in science content knowledge, the nature of science, and science as a way of knowing. Teachers are careful not to allude to their own bias or beliefs when teaching about controversial issues.

Accomplished science teachers ensure that students behave in an ethical manner in regard to science learning. They teach students to report research results accurately; to obtain permission and give all necessary citations when utilizing data from other researchers; not to cheat on assessments; to treat all living organisms in the classroom or encountered in the field in a humane, legal, and ethical way; to obtain

necessary permission for research on human beings and other living organisms; and to observe safety and confidentiality when collecting data from human subjects.

Reflective Practices

Accomplished science teachers reflect on whether they are teaching in a way that is responsive to the strengths and needs of their students; they realize students bring to the classroom a variety of exceptionalities and diverse cultural, ethnic, and linguistic backgrounds. Accomplished teachers reflect on whether they are reaching out to students and families in ways that ensure they all feel welcome and supported in an inclusive setting. Teachers make sure that their science classroom reflects the value of diversity in productive ways that engage students and demonstrate respect. Accomplished teachers are especially deliberate and thoughtful in reflecting on their students' backgrounds and abilities. They reflect on what they know about their students as learners, how they know it, and how they can apply this knowledge to improve instruction. If, through the process of reflection, teachers determine that there are significant gaps in their knowledge of their students' backgrounds that adversely affect science learning, teachers reflect on how they can remedy this lack. For example, if a teacher has a student with an exceptional need, the teacher may talk with other professionals, read articles, or seek out professional learning opportunities in order to learn more about the exceptionality and how to support and encourage students who bring that need to the classroom.

Accomplished science teachers continually reflect on their classroom practice in order to ensure that they are educating all students fairly and equitably. To aid in this endeavor, teachers avail themselves of many sources of relevant information. They may watch videos of classroom interactions, analyze assessment data, invite colleagues to observe their classrooms, and interview students. Teachers look for patterns that may indicate inequity, such as disproportionate rates of success or failure among certain groups of students or a consistent lack of engagement on the part of some individuals. If inequities are identified, teachers look for ways to ameliorate these situations. Accomplished science teachers scrupulously seek to uncover their biases and any other factors that may somehow undermine students' achievement in science. Accomplished teachers make every effort to prevent their personal biases from impacting their interactions with students.

Accomplished science teachers realize that ethical considerations are inherently complex; often there is no obvious best solution, and even careful decisions may have unforeseen consequences. Accomplished teachers reflect on their professional decisions, pondering whether they acted ethically and in the best interests of their students. Accomplished teachers solicit information from parents, students, and other school professionals, weighing all the available information in an attempt to provide a fair and equitable learning experience for all students. Accomplished teachers make sure their instructional practices conform to the highest ethical standards and acknowledge that judgments may need to be reconsidered over time as situations evolve and new information becomes available.

Standard IX

Reflection

Accomplished science teachers continually reflect on their teaching practice in order to maximize their own professional growth and improve the quality of their students' learning experiences.

Introduction

Accomplished science teachers possess a spirit of inquiry and embrace reflective conversations. They realize that successful reflection requires more than a willing attitude or a routine set of skills; it demands careful thought based on evidence. Accomplished science teachers understand that reflection is a tool for improving their practice. They know how to reflect effectively to maximize their own professional growth, which will ultimately lead to student learning. They understand the nature of reflection, the different types of reflection, and the purpose that reflection serves in enhancing student learning.

What Is Reflection?

For accomplished science teachers, reflection is the ongoing, intentional, introspective process of reviewing evidence from one's teaching practice with regard to one's educational goals, philosophy, and experiences. The purpose of reflection is to improve teaching and learning. Profound and productive reflection requires an open mind, genuine enthusiasm, professional integrity, and discipline. There are two main types of reflection: reflection on teaching and reflection in teaching.

Reflection on teaching is the deliberate, persistent, and thoughtful examination and contemplation of evidence resulting from the practice of teaching. Accomplished science teachers engage in this type of reflection outside the act of instruction in order to gain insights into their teaching practice, achieve new perspectives on education, and establish a record of their progress towards their goals. Accomplished teachers continuously and systematically examine, analyze, and evaluate all areas of their professional endeavors. They see reflection on teaching as a powerful mechanism for improving their practice.

Reflection in teaching is the process by which teachers reflect on their teaching as it is happening and make immediate adjustments—whether in thought or in action. Accomplished science teachers are able to respond quickly and purposefully as challenges arise and opportunities occur. For example, an experienced teacher

notices when an initial example does not resonate with students and quickly provides an alternative.

Accomplished science teachers take an inquiry stance in regard to their own practice. They make observations, propose hypotheses, collect evidence, identify patterns, and draw conclusions as a means to assess themselves and their work. Teachers then adapt, revise, and strengthen their teaching practice to improve student learning. Reflection reveals to teachers the evidence of their professional growth and suggests ways to proceed effectively in the future. (See [Standard III—Curriculum and Instruction](#).)

The Importance of Reflection

Accomplished science teachers are lifelong learners and members of learning communities who continually strive to advance their teaching practice. Teachers are aware of their personal strengths and weaknesses and use this knowledge to work toward achieving their professional goals. Accomplished teachers comprehend that reflection plays an important role in their improvement.

Accomplished science teachers have a vision for their students, the dynamics of their classroom, their own teaching role, and the future of the profession. As they reflect on their practice and assess its effectiveness, they adapt, revise, and strengthen teaching strategies to make learning more meaningful. They view each year as another opportunity to improve.

Accomplished science teachers seek opportunities for collaborative experiences that can support reflection. By collaborating with others, teachers are able to generate insights that they could not attain on their own. One goal of reflection is to better understand how new teaching practices can improve student learning. Reflecting with other teachers helps to reorient thinking, reaffirm effective decisions, reduce isolation, prompt further analysis, and attain important insights. Conversations with colleagues can provide a broader perspective and a more objective vision of one's own practice within a safe space for receiving constructive feedback. By including esteemed colleagues in the reflective process, accomplished teachers gain access to further expertise and a more complete perspective.

Accomplished science teachers know that self-reflection contributes to teachers' depth of knowledge and skill and adds dignity to their practice. Accomplished teachers ground their entire practice on a profound belief in the intellectual and academic merit of teaching. Reflection is therefore a critical element that improves and refines an accomplished science teacher's professional life. (See [Standard VII—Advancing Professionalism](#).)

Accomplished science teachers consider new pedagogical ideas and carefully evaluate the applicability of these innovations to their own teaching. These teachers can speak compellingly about why they make the pedagogical decisions they do. They clarify their instructional goals to students and adapt and extend resources to achieve

best practice. Accomplished teachers regularly reflect on student performance with respect to instructional goals in order to understand student learning and improve instruction. (See [Standard IV—Assessment](#).)

How to Reflect

Accomplished science teachers reflect on how curriculum, instruction, assessment, the fair and equitable treatment of students, and the learning environment all impact student learning. Teachers evaluate these elements in order to determine if their teaching generated the intended outcome. When it is appropriate to do so, accomplished teachers make modifications in their approaches. Teachers then reflect on the changes they have made and determine the impact of those changes on students' learning. This cycle repeats throughout the school year and throughout the teacher's career.

Accomplished science teachers understand that while reflection is an individual endeavor, collaboration is a powerful catalyst for reflection. When necessary, accomplished teachers proactively form groups for face-to-face discussion or seek out colleagues to collaborate with online. (See [Standard VII—Advancing Professionalism](#).)

Accomplished science teachers understand that reflection is not just snapshot summary at the end of a lesson, unit, or year. Rather, it is an ongoing process. Accomplished teachers reflect throughout the entire cycle of instruction. They recognize that the demands of high-quality science teaching change over time; indeed, they change with each class and each student.

Accomplished science teachers also understand that reflection must include attention to the student's role in the learning process. Accomplished teachers do not just focus on their own actions as instructors; they focus on how students engage in the learning process, asking themselves questions such as how much time students spend on task, what behavior problems students exhibit, and how often and in what manner students collaborate with each other. For example, as a measure of productive discourse a teacher may reflect carefully on how much time the teacher spends talking versus how much time students are talking.

To assist in reflection, accomplished science teachers gather evidence of their teaching such as videos, lesson plans, teacher-created instructional materials, student work, observation notes from colleagues, and photographs. These artifacts create opportunities to deepen analytic reflection because the artifacts enable teachers to uncover and question assumptions about student learning and their teaching.

Reflective Practice

Accomplished science teachers use their capacity for reflection to experiment with new approaches in a systematic and analytical fashion. Accomplished teachers reflect on the precise ways in which their instruction can be improved in order to

capitalize on their students' strengths, needs, learning profiles, and prior knowledge. For example, a teacher might ask questions such as, "Why didn't my students understand the phases of the moon? Why do they think that clouds cause the phases? How can I lead them to confront their developing concepts and facilitate the development of the accepted scientific explanation?" Teachers anticipate student responses and are consistently able to take advantage of the unplanned opportunities that present themselves over the course of the school day in ways that are meaningful to students. For example, if a student asks a question that is loosely related to the class discussion, an accomplished teacher is capable of weaving the new idea into the fabric of the lesson while maintaining the focus of the lesson and student engagement. Accomplished science teachers are aware that reflection must be developed and practiced regularly if it is to become embedded in their practice. (See [Standard 1—Understanding Students](#).)

As part of reflective practice, accomplished science teachers identify and implement tools to measure the success of their innovations. Accomplished teachers understand that highly useful tools for reflection could include videos and journals. Videos of their own teaching allow teachers to replay events to capture key evidence of implementation or the impact of an aspect of teaching. Reflective journals allow a teacher to document progress; preserve thoughts, feelings, and insights for future analysis; and project future goals. For example, a strategy to improve classroom discourse could include a chart to keep track of factors such as how often teachers engage specific students, how much time teachers spend talking versus fostering opportunities for student interactions, and whether there is any evidence of bias in the classroom. The teacher would then use the results of the observations to determine the effectiveness of the innovation.

Reflection is centered on student progress; therefore, accomplished science teachers involve students in providing rich contexts for teacher reflection. For example, a teacher might use exit cards every day and reflect on student responses before finalizing the instructional plan for the following lesson. Alternatively, a teacher might focus on interactions with students, such as group discussions or student interviews. For example, a teacher might use a fishbowl activity related to the norms of the scientific community in which a small group of students and the teacher sit in a circle of desks in the middle of the room while the rest of the students remain on the outside. The teacher would facilitate a discussion within the inner circle while the students in the outer circle observe. Then the teacher would give those in the outer ring a chance to summarize and expand on the conversation. Finally, an accomplished teacher would use the observations of the second group of students to improve the instructional process and enhance the learning environment.

Accomplished science teachers make time, find space, seek out support, capitalize on professional learning opportunities, develop learning communities, devise creative ways to collect evidence, and define clear professional goals for themselves in order to improve reflective practice. Accomplished teachers make every effort to remain objective as they collect evidence, seek outside opinions, and draw conclusions. Accomplished teachers understand the complexities of teaching

and learning and recognize that all actions occur within a context. Accomplished teachers move forward with reflection persistently but cautiously, remembering to be constructive, to not take criticism too personally, and to represent their practice honestly.

When to Reflect

Accomplished science teachers take time to reflect, and they know that the reflection process must be ongoing, not just a summative activity after a test, quarter, or semester. Teachers reflect in the moment to alter their instructional actions in response to student feedback. Accomplished teachers reflect when there is a serious disruption, when a dilemma arises, to capitalize on success, or when working toward a professional goal. Accomplished teachers view each year, each day, and even each lesson as another opportunity to improve the quality of their own teaching practice and to enhance the knowledge and stature of their profession, and they make reflection a regular part of their routine.

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The National Board for Professional Teaching Standards (NBPTS) is deeply grateful to all those who contributed their time, wisdom, and professional vision to *Science Standards, Third Edition*. Any field grows, shifts, and evolves over time. Standards, too, must remain dynamic and therefore are subject to revision. In 2011, NBPTS convened a fifth Science Standards Committee. This committee was charged with achieving both continuity and change, using the previous editions of the standards as the foundation for its work but modifying the standards to reflect best practices of the early twenty-first century. The 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 committee co-chairs Julie Angle, NBCD and Dat Le, NBCT, for their invaluable leadership in making the third edition a reality.

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