SPIR STANDARDS FOR HIGH-QUALITY K-12 SCIENCE EDUCATION

POLICY AND ADMINISTRATIVE SUPPORT OF THE SCIENCE PROGRAM	
Standard 1: GOALS	A multi-year plan with clearly-stated goals guides development and improvement of the science program.
Standard 2: DISTRICT SUPERVISION	A leadership team supervises implementation of a comprehensive, coherent science program.
Standard 3: COMPLETE CURRICULUM	A rigorous, complete curriculum describes what all students should know and be able to do in science and high-quality instructional materials support its implementation.
Standard 4: RESOURCE ALLOCATION	The science program Is supported by adequate resources, facilities and equipment.
CLASSROOM IMPLEMENTATION OF SCIENCE CURRICULUM	
Standard 5 LEADERSHIP	Leadership of administrators, teachers, and instructional coaches provides guidance, support and accountability for implementation of the science program
Standard 6: INSTRUCTION	Instruction develops student understanding of important science concepts, including scientific inquiry, and connects science learning to other subjects.
Standard 7: MATERIALS MANAGEMENT	Instruction is supported by adequate materials supplied in a manner that minimizes classroom preparation time.
CULTURE OF HIGH EXPECTATIONS	
Standard 8: CLASSROOM CULTURE	Classroom interactions develop positive attitudes toward learning science and model scientific inquiry.
Standard 9: PROFESSIONAL DEVELOPMENT	Teachers continually improve their abilities to help students learn science through participation in a professional learning community
Standard 10: EQUITABLE ACCESS	All students experience the standards-based curriculum and the school environment values achievement and contributions of all individuals
Standard 11: STUDENT ASSESSMENT	Student assessments are aligned with the curriculum, appropriate in form, and develop student responsibility for learning.
Standard 12: HIGHLY-QUALIFIED TEACHERS	Students receive instruction from teachers who are academically certified in the science content and demonstrate best practices in science instruction.
Standard 13: ENGAGED COMMUNITY	Parents and the community receive frequent communications and opportunities to participate in goal setting, instructional support, and program evaluation.
ACCOUNTABILITY	
Standard 14: DATA-DRIVEN DECISION MAKING	Assessment/evaluation data are used to improve the science program.
Standard 15: RESULTS	Indicators of student success are positive and improving.

Standard 1: DISTRICT GOALS
A multi-year strategic plan with clearly-stated goals guides development and improvement of the science program.

An exemplary science program is created by thoughtful and sustained efforts guided by a shared vision of best practices in science teaching and learning. A strategic planning process includes developing goals to attain a shared vision, building consensus on the goals, and implementing a multi-year strategic plan. When all stakeholders in the success of the science program are guided by such a plan, efforts are coordinated, new policies and practices complement one another, and resources are optimized.

Goals at the school level are addressed in Standard 5, and should align with district goals.

A. Goals for the district science program have been developed collaboratively.

B. A multiyear district plan includes all aspects of the program and goals that are specific as to desired outcome, timeline, and responsible person.

C. All staff are accountable for implementing the goals of the science program.

Key Resources:

- For more information about SMART goals, see Conzemius, A. & O'Neill, J. (2002) *The handbook for SMART school teams.* Bloomington, IN: National Educational Service, p. 4.
- For advice on avoiding pitfalls and using strategic planning to build effective learning communities, see Schmoker, M. (February 2004) *Tipping Point: From Feckless Reform to Substantive Instructional Improvement.* Phi Delta Kappan V.85 No.6, pp. 424-432. Retrieved 7-13-2007 from http://www.pdkintl.org/kappan/k0402sch.htm
- For a scholarly review of planning models and many references, see Hambright, G. & Diamantes, T. (2004) *Definitions, Benefits and Barriers of K-12 Educational Strategic Planning.* Journal of Instructional Psychology, Vol. 31, 2004. Retrieved 7-13-07 from http://findarticles.com/p/articles/mi_m0FCG/is_3_31/ai_n6332794/pg_1

Standard 2: DISTRICT SUPERVISION
A district team supervises implementation of a comprehensive, coherent improvement process.

An exemplary science program is a result of careful planning and continual monitoring with a common vision of teaching and learning in mind. The "what" of the monitoring grows out of the goals and plans described in Standard One. The "how" of the monitoring benefits most from leadership well-acquainted with best practices in science education and a strong collaborative relationship between policy-makers, service providers, and teachers. The expertise needed to foster significant improvements is rarely, if ever, found in one person. Instead, an array of traits is needed to lead educational change. (Marzano, Waters & McNulty, 2006) A team of individuals with varied expertise, working with a comprehensive strategic plan, will accomplish what no supervisor, coach, principal, or teacher could do alone.

Likewise, no one area is "central" to improvement. Attention must be paid to all aspects of the science program--the curriculum, instruction, assessment, professional development, materials management, community support, and the varied needs of the teachers and student population. And since even the most careful plans are hypotheses, pertinent data must be continually collected and analyzed in order to manage the change process and revise plans.

A. A comprehensive plan for monitoring, assessing and supervising the science program drives improvement

B. Multiple sources of data are used to set district goals and allocate resources for the science program.

Key Resources:

- Love, N. (2004) *Using data/getting results: A practical guide for school improvement in mathematics*

  and science. Norwood, MA: Christopher-Gordon Publishers.
- A rich discussion of planning how-to's can be found in Chapter 4 *Science for all children: A guide to Improving elementary science education in your school district* (NRC, 1999). The information is easily adaptable for use with all grades, and is also available online at http://www.nsta.org/about/positions/laboratory.aspx.
- Marzano, R., Waters, T. & McNulty, B.(2006) *School leadership that works.* Alexandria, VA: Association for Supervision and Curriculum Development.

Standard 3: COMPLETE CURRICULUM
A rigorous, complete curriculum describes what all students should know and be able to do in science, and high-quality instructional materials support its implementation.

Curriculum development begins with science standards provided by the state and informed by the content of national standards -- *National Science Education Standards* or *Benchmarks for Science Literacy.* However, since standards are not intended to themselves be a curriculum (NRC, 1996, p.1) a standards-aligned curriculum will organize the content of the standards into a series of science learning experiences for each grade or course. The organization of the curriculum must reflect four qualities--the curriculum must be:

- Comprehensive, including the content areas of scientific inquiry, life science, physical science, earth (and space) science, science and technology, science in personal and social perspectives, and the history and nature of science. (NRC, 1996)
- Rigorous, so that students are appropriately challenged with high expectations at all levels, and the total program produces students who understand and can apply knowledge of a broad range of science concepts and scientific thinking. (NRC, 1996)
- Vertically integrated, so that each grade's content prepares students for future studies and the total program provides comprehensive coverage. (AAAS, 1999, 2007)
- Research-based, so that content is presented in a learning progression, with attention to appropriately increasing levels of abstraction and to common misconceptions. (NRC 2007)

The curriculum for science should be "guaranteed" (Marzano, *et al,* 2005) to all students through use of a rigorous, standards-based curriculum that can be successfully implemented in the available instructional time. Many curricula are overstuffed, resulting in superficial instruction and lack of student understanding (Schmidt *et al, 1999*). Helpful implementation tools include curriculum guides that describe "big ideas" (Wiggins & McTighe, 2005) to focus instruction, and pacing guides that provide timelines for instruction

A. The curriculum is rigorous and complete.

B. Instructional materials align with the curriculum

C. High-quality instructional materials are supplied for each grade or course.
Instructional materials enable the curriculum to be delivered, and may include teacher guides, student books, kits of materials, software, supplemental reading materials, and such.

D. All students have access to the complete curriculum.

Key Resources

- Representing a consensus of scientists and science educators on what defines complete and appropriately rigorous science curriculum see: National Research Council (1996), *National Science Education Standards.* Washington, DC: National Academies Press.

- Describing a complete science curriculum and almost completely aligned with the NRC standards (above), also see: American Association for the Advancement of Science, (1995) *Benchmarks for Science Literacy.* New York: Oxford Press.
- A description a design process for a science curriculum can be found in: National Research Council (1999*) Designing Mathematics and Science Curricula*. Washington, D.C.: National Academies Press. See page 31 for an overview graphic. (Also available online at www.nap.edu)
- An excellent guide for vertical integration and learning progressions of science topics consult: American Association for the Advancement of Science (1999 and 2007) *Atlas of Science Literacy (1st and 2nd Eds.)* New York: Oxford Press.
- Learning progressions and the research-based rationale for their role in the science curriculum can be found in: National Research Council (2007) *Taking science to school: learning and teaching science in grades K-8.* Washington DC: National Academies Press.
- For more information on curriculum design and implementation focused on developing student understanding: Wiggins, G., and McTighe, J. (2005). *Understanding by design (2nd ed.).* Alexandria, VA: Association for Supervision and Curriculum Development.
- The most authoritative information on the nature of the U.S science curricula and the source of the description "a mile wide and an inch deep" began with the curriculum study associated with the Third International Mathematics and Science Study (TIMSS). A key publication is: Schmidt, W., McKnight, C. and Raizen, S. (eds.) (1999) *A splintered vision: An investigation of U.S. science and mathematics education.* New York: Springer.
- For more detail on a "guaranteed curriculum" see: Marzano. R., Waters. T., & McNulty, B. (2005). *School leadership that works: From research to results.* Alexandria, VA: Association for Supervision and Curriculum Development.
- For eye-opening examples of what traditional topics might be deleted from the science curriculum, see Chapter 7 "Unburdening the Curriculum" in: Association for the Advancement of Science. (2000) *Designs for science literacy.* New York, Oxford Press.
- For numerous examples of science concepts or "big ideas" around which a meaningful curriculum is built, see: Keeley. P. (2005) *Science curriculum topic study.* Thousand Oaks, CA: Corwin Press.
- For guidelines to help with implementation*: (1996) NSTA pathways to the science standards: Guidelines for moving the vision into practice.* High School, Middle School, or Elementary Edition. NSTA Press.

Standard 4: Resource Allocation
The science program Is supported by adequate resources, facilities and equipment

A science classroom should look different from a mathematics or history classroom. Learning to think scientifically and understand science concepts requires that students participate in observing and manipulating elements of the natural world, investigating cause and effect, practicing scientific process skills, and conversing with other investigators. Facilities and equipment are necessary to support this learning environment.

Basic classroom facilities include space for materials for observation and manipulation, flat surfaces that allow exploration, and water. For more advanced classes, basic facilities also include adequate electric and gas outlets, sinks, and fume hoods. To provide adequate space and supervision, science classes ideally will not exceed 24 students. Classroom arrangements at all levels should allow for transitions between whole and small group instruction, demonstrations and presentations, and individual work. Additional space to prepare materials will benefit teachers with more than one class daily. Storage facilities are essential to maintain a safe and accessible inventory of materials and leave work spaces uncluttered

Active participation in observing scientific phenomena is critical to learning science, but requires attention to ensuring safety. Every teacher must understand and communicate to students how and why they must use safety procedures. Curriculum guides should detail safety procedures and necessary equipment, such as protective eyewear, fire extinguishers, and in some high school classes, eye wash stations and emergency showers. Proper facilities are essential in order to ensure that all students have rich and authentic science learning experiences.

How do budget-conscious schools meet the challenge of providing adequate facilities and equipment? In order to provide the necessary resources, districts often look to community partnerships and grant funds.

Doing so requires the development of a mutually beneficial working relationship with science-interested businesses, industries, community organizations and institutions of higher education. (Also see Standard 13: Engaged Community) The considerable expense of materials for science must be backed by frugal systems of sharing resources among classrooms, as well as centralized maintenance and refurbishment systems. (Also see Standard 7: Materials Management)

A. Science facilities provide space, equipment, and storage to support effective instruction.

B. Facilities and equipment provide a safe learning environment.

C. Administrative and community support ensures adequate financial support for the science program, through school funding, donations, and grant-funded programs.

Key Resources

- Responsibilities of science teachers, district administrators, and school boards for safety in the science classroom are outlined in NSTA's position statement, *Liability of Science Educators for Laboratory Safety*.(2007) Also see the position statements on, *The Integral Role of Laboratory Investigations in Science Instruction*, http://www.nsta.org/about/positions/laboratory.aspx and *Learning Conditions for High School Science*.
- Instructional concerns about safety are elaborated on in three volumes: Texley, J., Kwan, T. and Summers, J. (2004) *Investigating safely: A guide for high school science.* Arlington, VA: NSTA Press, as well as *Investigating safely: A guide for middle school teachers,* and *Exploring safely: A guide for elementary teachers*.
- NSTA publishes flipcharts for elementary and middle school classrooms addressing how to prevent or solve safety problems.
- For details on facilities, see Motz, L, Biehle, J, & West, S (2007) *NSTA Guide to Planning School Science Facilities, Second Edition*. Arlington, VA: NSTA Press.
- For a compendium of "Scope on Safety" columns from Science Scope see Roy, Kenneth Russell (2007) *The NSTA Ready-Reference Guide to Safer Science.* Arlington, VA: NSTA Press.
- Community collaboration in schools and development of partnerships to support science education needs can be found throughout the nation through universities, community agencies and organizations, private foundations, and Federal programs such as the National Science Foundation, U.S. Department of Education, and National Institutes of Health. NSTA publications and website often publish information on the status of various potential sources of information and funding.

Standard 5: SCHOOL LEADERSHIP
Leadership of administrators, teachers, and instructional coaches provides guidance and accountability for implementation of the science program

Building and maintaining an exemplary science program requires sustained and coordinated efforts of all staff. Every member of the staff needs to understand the goals and their role in achieving them. Actions and accountability are spelled out in a plan that is specific as to steps, timeline, how progress will be measured, and who is responsible. Then, department or staff meeting agendas are opportunities to discuss progress, hear reports, and solve problems as they arise.

Since not all administrators have a background in science content and pedagogy, the school plan and those appointed to various responsibilities provide shared expertise and leadership. As a team, teachers, coaches and administrators together lend expertise in content and teaching, encourage and support one another, and share responsibility for student success in learning science. Principals remain responsible for maintaining focus, leveraging resources, and ensuring accountability for the agreed-upon goals and responsibilities.

A. A school plan coordinates efforts and defines accountability.

B. **Classroom support and mentoring accompany high expectations for teachers in achieving improvement goals.**

C. **Teachers have opportunities to learn and practice leadership skill.**

Key Resources

- The role of planning in educational improvement is detailed in: Carr, J. & Harris, D. (2001). *Succeeding with standards: Linking curriculum, assessment, and action planning.* Alexandria, VA: Association for Supervision and Curriculum Development. Also see Standard 14: Data-Driven Decision Making.
- Learn what leadership traits are most successful in managing change in: Marzano, R., Waters, T. & McNulty, B. (2005) *School leadership that works: From research to results.* Alexandria, VA: Association for Supervision and Curriculum Development.
- For more about creating a professional learning community, see: DuFour, R. & Eaker, R. (1998). *Professional learning communities at work: Best practices for enhancing student achievement.* Bloomington, IN. National Educational Service.
- Don't let the pitfalls on the road to change catch you by surprise. Access the research on change, such as: Bridges, W. (2003) *Managing transitions*: *Making the most of change* (2^{nd} Ed.). Cambridge, MA: DeCapo Press.
- A. Zmuda. (2004) *Transforming schools: Creating a culture of continuous improvement*. Arlington, VA. Association for Supervision and Curriculum Development.

Standard 6: INSTRUCTION
Instruction develops student understanding of important science concepts, including scientific inquiry, and connects science learning to other subjects.

A curriculum is just a stack of paper until a teacher plans and delivers daily learning experiences that develop student understanding of the important ideas. The teacher's planning process should focus on what the students will know or be able to do as a result of instruction, and the progression of learning experiences should be designed with these ends in mind. Likewise, instructional strategies will vary according to the type of knowledge being developed. For example, procedures are learned through watching and practicing and inquiry abilities are acquired through inquiry experiences that progress from teacher-guided to more student-initiated. Students should have the benefit of multiple approaches to develop their understanding, such as varied groupings, varied modes of instruction, and opportunities to revise and improve their work.

Learning to understand science demands that instruction reflect the practice of science. As scientists do, students need experience asking questions, observing, collecting and analyzing data, developing and communicating explanations based on data. As scientists do, students need to learn the existing body of scientific knowledge from experts, and come to understand how that knowledge is continually generated by presenting findings, challenging peers, and participating in discussions based on evidence. (Also see Standard 8: Classroom Culture)

Teachers with a well-developed repertoire of formative assessments and a good working relationship with their students can best develop student understanding of the curriculum content. Instruction should be modified as a result of assessment findings—slowed down, expanded, or skipped. Instruction is enhanced when students are clear on what is expected of them, learn how to monitor their own learning, and are able to demonstrate their understanding in a variety of ways.

Connecting science learning with other subjects whenever feasible is desirable due to both research on how people learn and to the voluminous demands of the over-all curriculum. Science content can motivate student engagement in reading, writing, oral discourse, and math. Applying literacy skills in science provides valuable dual opportunities for students to apply their understanding and skills in new contexts.

A. **Teachers plan instruction aligned with the curriculum and designed to help students understand science concepts.**

B. Instruction is designed to help students learn to think scientifically and understand the nature of science.

C. Formative assessments guide teachers' decisions about instruction.

D. Teachers often capitalize on opportunities to connect science with other subjects.

Key Resources

- For thorough, credible research and applications, see Donovan, S. & Bransford J. (Eds.) (2005) *How students learn: History, mathematics and science in the classroom.* Washington, DC: National Academies Press; and its preceding research report, Bransford J., Brown, A. & Cocking, R. (eds.) (1999) *How People Learn*: *Brain, mind, experience and school.* Washington, DC: National Academies Press.
- The recommended frequency and content of laboratory investigations is detailed in NSTA's official position statement: *The integral role of laboratory investigations in science instruction,* available online at http://www.nsta.org/about/positions.aspx#list .
- For a comprehensive research report on how K-8 students learn science, see Duschl, R., Schweingruber, H, and Shouse, A. (eds.) *Taking science to school: Learning and teaching science in grades K-8.* Washington, DC: National Academies Press.
- Among many resources that develop an deeper understanding about science inquiry, see: National Research Council. (1999) *Science inquiry and the national science education standards.* Washington, DC: National Academies Press.
- A thorough general guide for implementing inquiry is: Llewellyn. D. (2001) *Inquire within: Implementing inquiry-based science standards.* Thousand Oaks, CA: Corwin Press
- Researchers developed indicators of high quality science and mathematics instruction and undertook studying a national sample which is presented in the report: Weiss, I. *et al.* (May 2003) *Looking inside the classroom*: A study of K-12 mathematics and science education in the United States. Chapel Hill, NC: Horizon Research Institute.
- A brief, research-based guide to formative assessments can be found in Black, P. & Garrison, C. (2004) *Science inside the black box: Assessment for learning in the science classroom.* London, UK: InferNelson Publishing Company Ltd.
- Defining information and research descriptions can be found in Atkin, J., Black, P. & Coffey J. (2001) *Classroom assessment and the national science education standards.* Washington, DC: National Academies Press.
- Among the many resources on assessment in science education published by NSTA Press, see: Atkin, J. & Coffey, J. (Eds.) (2003) *Everyday assessment in the science classroom.* Arlington, VA: NSTA Press. And also, Atkin *et al*. (2005*) Designing everyday assessment in the science classroom.* New York: Teachers College Press.
- In order to integrate literacy skill development through science instruction, teachers of science need to learn how to develop reading skills, as in: Barton, M. & Jordan, D. (2001) *Teaching Reading in Science.* .Alexandria, VA: Association for Supervision and Curriculum Development. And Their, M. & Daviss, B. (2002) *The new science literacy: Using language skills to help students learn science*. Portsmouth, NH: Heinemann Publishing*.*
- For an award winning publication of current NSF funded research on science and literacy with engaging real life case story examples see Douglas, R, Worth, K, Klentschy, M and Binder W. (2006) *Linking science and literacy in the K–8 classroom* Arlington, VA: NSTA press:
- The use of science notebooks is a valuable aid in developing student understanding of science concepts while also developing writing, communication and critical thinking skills. A comprehensive, practice-based resource can be found at *www.sciencenotebooks.org*

Standard 7: Materials Management
Instruction is supported by adequate materials supplied in a manner that minimizes teacher preparation.

Observing science phenomena and managing scientific investigations are central to learning science. Managing the necessary materials can be a challenge for teachers of science. School districts with successful science programs support classroom learning by supplying materials to classrooms to enable student exploration, observations, and analysis. Teachers benefit from assistance in preparing, refurbishing, and ordering replacements for consumable materials provided by paraprofessionals or volunteers in a central or site-based facility. Centrally managing materials can facilitate cost-effective resource sharing, bulk buying, and program monitoring.

While “low-tech” materials, such as scales, stop watches, thermometers, and microscopes are routinely used in science instruction, modern science investigations benefit from the power of technology to empower close observation, enable rapid collecting and processing of data, extend the senses, and expand the reach of the classroom to data sources of scientific instruments such as satellites, world-wide networks and webcams. Teacher demonstrations and student presentations can also be more engaging and accurate using projected microscopic images or computer or calculator generated graphs.

Opportunities to integrate multimedia resources with science learning also help teachers provide more engaging learning environments and meet needs to extend the curriculum to student interests and further research.

A. Materials are supplied to classrooms in a convenient, cost-effective manner.

B. Technological equipment supports and enhances learning. *Requirements will vary due to the age of the students as well as the science content, but use of scientific equipment in student inquiry should be found throughout all grades and courses.*

C. Multimedia supplements to the science program are up-to-date, and readily available for classroom use.

Key Resources

- The Association for Science Materials Centers has a website www.kitsupport.org with information on technical assistance, conferences, and grants, all focused on materials management. Under “members” are lists of materials centers by state, including some links to some websites maintained by individual materials centers.
- For an introduction to the basics of materials centers, the“five Ss” of successful materials support—service, space, staff, stuff, and savings,” see Peters, T. (Summer 2004) “Is A Materials Resource Center Right For You?“ *Science and Children,* Arlington, VA: National Association of Science Teachers. Also available at http://www.ces.clemson.edu/smtg/data/p20-23peters.pdf
- A general description of science materials management can also be found in a National Research Council publication (1999) “Establishing A Science Materials Support Center”, *Science for all children: A guide to Improving elementary science education in your school district* Washington, DC: National Academies Press, pp. 89-100.
- For specific learning goals regarding use of technological tools, see the “Habits of Mind” chapter, “Manipulation and Observation” section in: American Association for the Advancement of Science (1999) *Benchmarks for science literacy.* New York: Oxford Press.
- NSTA journals and website feature *NSTA Recommends*, which offer descriptions of print materials receiving positive reviews by expert science educators, accessible by topic on the website.
- Some publishers of instructional materials offer lists of recommended books to enrich and extend science learning. See the teachers guides or contact publishers for more information.
- *Science Books & Films,* published bimonthly by the American Association for the Advancement of Science and available by subscription online, contains reviews of print, audiovisual and electronic resources for use in science, technology and mathematics education at the elementary, middle and secondary levels.

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Standard 8: CLASSROOM CULTURE
Classroom interactions develop positive attitudes toward learning science, model scientific inquiry, and support persistence in learning among the students.

A positive classroom culture is as essential to student learning as is the curriculum or teacher’s expertise in the content. First, students need to feel confident about their ability to learn science, since an unfortunate negative bias persists that learning science is hard and only relevant for a few. Now, in a standards-based learning environment, all students are expected to become proficient in science and the science classroom culture must welcome and support all students. Positive attitudes are fostered when students feel the teacher cares about them, their peers also support them, the tasks are interesting, and learning resources are available. (Marzano, 1992) The teacher must have a working relationship with students that continually assesses their developing understanding of science concepts and tailors instruction for optimal success.

Secondly, understanding science means understanding how science knowledge comes to be. The classroom should reflect the practice of science in modeling and applying scientific inquiry, valuing data-driven conclusions, and being open to peer review and replication. The history of science also provides numerous examples of the value of creative, flexible thinking in opening new vistas in understanding our natural world, so the classroom culture should likewise welcome students' alternative explanations—subject to scientific verification—and creative approaches to investigations. Scientists agree that there is no one "scientific method."

Finally, research on learning has shown that teacher comments referencing learning criteria will encourage students to keep learning, while grades tend to end the individual learning process (Butler, 1997).The classroom climate will improve and learning will increase when grading practices focus on students' reaching mastery of the material given the time and remediation necessary, and ongoing feedback is largely substantive comments on student work.

A. The working relationship between science teachers and students models scientific inquiry and supports scientific thinking.

B. Classroom interactions consist of two-way communications (teacher and students, among students) that assist the teacher in understanding the student's thinking and support the student in making the best effort to master the knowledge and skills.

C. Students have a positive attitude about their ability to succeed in learning science because they find the tasks interesting, know what is expected of them in showing they understand, and feel they have adequate resources and time to develop their full understanding.

D. Teacher feedback encourages and rewards persistence and effort to learn.

Key Resources

- For the original research report on comments vs. grades, see: Butler, Ruth (1997) *Task-involving and ego-involving properties of evaluation: effects of different feedback conditions on motivational perceptions, interest, and performance.* Journal of Educational Psychology, 79(4), 474-482,
- For practical and encouraging advice on providing feedback through comments see: Black, P, & Harrison, C. (2004) *Science inside the black box: Assessment for learning in the science classroom.* London, UK: nferNelson.
- For specific indicators of high-quality classroom culture, see: Weiss, I. *et al.* (May 2003) *Looking inside the classroom*: A study of K-12 mathematics and science education in the United States. Chapel Hill, NC: Horizon Research Institute.
- From a research meta-analysis, the nine most effective instructional strategies: Marzano, R., Pickering, D, & Pollock, J. (2004) *Classroom instruction that works: research-based strategies for increasing student achievement*. Alexandria, VA: Association for Supervision and Curriculum Development.
- For a practical description of the conditions under which students learn best, see Marzano, R. (1992) *A different kind of classroom: teaching with dimensions of learning*. Alexandria, VA: Association for Supervision and Curriculum Development.
- An introduction to research-based grading can be found in Marzano, R (2006) *Classroom assessment & grading that work.* Alexandria, VA: Association for Supervision and Curriculum Development.

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Standard 9: PROFESSIONAL DEVELOPMENT
Teachers continually improve their abilities to help students learn science through participation in a professional learning community.

Exemplary science programs thrive in a professional culture of learning and continuous improvement. A professional learning community unites school and district administrators with the teachers in focusing on student learning and strives to eliminate gaps between expectations and practice. Communication flows in all directions within a learning community. For instance, new information on science instruction provided in district-planned professional development will be modeled and monitored in classrooms, and discussed by groups of teachers during implementation. Further, teachers' needs will inform the planning of professional development and other goal-setting for the science program.

A learning community is characterized by "open doors." That is, the site administrator's office is regularly visited by science teachers, and science classroom and planning time regularly involves the administrators. To be more specific, teachers expect administrators to be vitally interested in the progress in each science classroom and ready to assist with encouragement, resources, and practical problem-solving. Administrators expect teachers to implement the curriculum, support other teachers, share resources, propose solutions to challenges and participate fully in improving student achievement.

With an unwavering focus on student learning, the community will give top priority to high expectations, successful instructional practices, and meeting the professional development needs of each individual within the community—from new teacher to veteran. The bulk of professional development will be imbedded in classroom practice and learning by doing, but opportunities to deepen content knowledge, engage in research on learning or in science, and share classroom experiences will help all teachers continually improve. .

A. A culture of learning focuses attention on student learning, examines teacher practices, and supports continual improvement among all teachers of science.

B. Professional learning focuses on developing student understanding of key science concepts.

C. Professional learning focuses on how students learn science.

D. Professional learning continues throughout a teacher's career through diverse activities both outside and inside the classroom.

Key Resources

- To build an intellectual framework for planning excellent professional development, become acquainted with the "five levels" in: Guskey, T. (1999) *Evaluating professional development.* Thousand Oaks, CA: Corwin Press.
- For a comprehensive overview of professional development for science teachers, see: Loucks-Horsley, S, Love, N., Stiles, K. Mundry, S., & Hewson P. (2003) *Designing professional development for teachers of science and mathematics (2^{nd} Ed.).* Thousand Oaks, CA: Corwin Press.
- To learn from the experiences of others, browse: Yager, R. (Ed.) (2005) *Exemplary Science: best practices in professional development.* Arlington, VA: NSTA Press.
- For practical implementation structures for a professional learning community, start with: Eaker, R., DuFour, R. & DuFour, R. (2002) *Getting started:*
- *Reculturing schools to become professional learning communities.* Bloomington, IN: Solution Tree

Standard 10: EQUITABLE ACCESS
The standards-based curriculum is available to all students, and the school environment values achievement and contributions of all individuals

Can some people get along just fine without science knowledge? Today, the answer must be “no.” Basic scientific literacy is necessary for making decisions in personal health, understanding advertising claims, making best use of technological advances, participating in local and national elections, and protecting the global environment, to name a few important areas. Not everyone will become a scientist, but everyone will benefit from learning to think scientifically and understand how the natural world works.

Education itself has transformed over the last century from a privilege for the few to an entitlement for all. The recent standards movement has at its heart an endeavor to identify what all students should know in each subject. In developing the *National Science Education Standards* (1996), participating scientists and educators came to consensus on what “all students, regardless of age, sex, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science, should have the opportunity to attain.” (p. 20)

School policies, as well as science curricula, must allow for this standard to be implemented by enabling all students to take science classes and to succeed in learning the key concepts of the curriculum at each level. In doing so, both equity and excellence must be maintained.

A. Adequate instructional time is available and used to implement the science curriculum.

B. Expectations for learning the complete science curriculum are uniformly high across all student populations, and school policies and practices support access and success for all.

C. Intervention strategies ensure that students who are falling behind receive help in developing their understanding, time to demonstrate their understanding, and opportunities to replace a failing grade.

D. Students who are more able or interested in a science topic have opportunities to extend their study, both in classes and through outside activities.

Key Resources:

- The NSTA official position: The Integral Role of Laboratory Investigations in Science Instruction (Feb. 2007) found at www.nsta.org contains expectations on instructional time and the character of instruction.
- Guidance for the content of high school courses and the critical role of student investigations is found in: Susan R. Singer, S. Hilton, M. & Schweingruber, H, *Eds*, (2005) *America's Lab Report: Investigations in High School Science* Washington, DC: National Academies Press.
- An NSTA position statement, *Gender Equity in Science Education (2003),* found at www.nsta.org provides suggestions for instruction, administration and teacher education. Another, *Multicultural Science Education (2000),* outlines declarations supporting inclusion of all children.
- An article published by Learning Points Associates (2005), *Remembering the Child: On Equity and Inclusion in Mathematics and Science Classrooms*, found at http://www.ncrel.org/sdrs/areas/issues/content/cntareas/math/ma800.htm succinctly defines equity issues, provides practical guidance and contains valuable references.
- This article provides an introduction to key indicators for measuring equity in science programs: Hewson, P. *Toward Equity in Science Instruction* available at http://www.wcer.wisc.edu/news/coverStories/toward_equity_science_instruction.php
- An exhaustive reference for specific instructional strategies for various inclusion challenges is found in: Stefanich, G.(n.d.) *Creating Inclusive Science Education*, available at http://www.wcer.wisc.edu/news/coverStories/toward_equity_science_instruction.php

Standard 11: STUDENT ASSESSMENT
Student assessments are aligned with the curriculum, appropriate in form, and develop student responsibility for learning.

The results of student assessments typically have two main applications: one use is to adjust the content or pace of instruction so that more students will achieve understanding, and this is the application addressed by this standard. The second main application is to assess the overall effectiveness of the science program, and that application is addressed under Standards 14, Data-Driven Decision Making, and 15, Results.

Students start learning about their world and constructing their own explanations long before they begin formal education in science. Since their early explanations are based on limited experience and naïve logic and reasoning, it shouldn't be surprising that children bring to school some very unscientific explanations. Instruction, therefore, often produces some unpredictable results, as students attempt to reconcile their pre-conceptions with experimental results and scientific explanations. Teachers must continually monitor student understanding to reassure themselves that instruction is having the desired result, and to plan the appropriate next steps in guiding students toward correct, scientific explanations.

Classroom interactions can be structured in many ways to assess student understanding, from crafting teacher questions to observing student actions, to looking at student work samples, to designing a written test. Best practices include aligning assessment content to the curriculum, choosing the best form of assessment for the knowledge or skill being assessed, and developing in students their abilities to take active responsibility for their own learning.

A. The content of student assessments is aligned with the curriculum.

B. The forms of student assessments are varied and appropriate for the knowledge being assessed.

C. Students learn to take responsibility for their own learning.

Key Resources

- A brief but very powerful guide to student assessment in science is found in: Black, P, & Harrison, C. (2004) *Science inside the black box: Assessment for learning in the science classroom.* London, UK: nferNelson.
- Crafting the right questions to reveal student thinking became a lot easier with the publication of: Keeley, P. (2005) *Uncovering Student Ideas in Science: 25 Formative Assessment Probes, Volume 1* and (2007)*Uncovering Student Ideas in Science: 25 MORE Formative Assessment Probes, Volume 2* Arlington, VA: NSTA Press.
- A research-based overview of classroom assessment varieties and forms can be found in Chapter Three of: Atkin, J., Black, P., & Coffey, J. (2001) *Classroom assessment and the national science education standards*. Washington, DC: National Academies Press.
- NSTA publishes several books on student assessment in science. See www.nsta.org/sciencestore for a current list.
- A traditional framework for a range of cognitive demand dates from the 1950's in "Bloom's Taxonomy". An overview can be found at http://en.wikipedia.org/wiki/Taxonomy_of_Educational_Objectives. A more recent taxonomy can be found in: Marzano, R & Kendall, J (2006) *The new taxonomy of educational objectives.* Thousand Oaks, CA: Corwin Press.

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Standard 12: HIGHLY-QUALIFIED TEACHERS
Students receive instruction from teachers who are academically certified in the science content and demonstrate best practices in science instruction.

Qualified teachers are an essential part of a science program, but what is a highly qualified science teacher? A science teacher needs to have two equally important areas of expertise, science content and how science is learned. And, like no other subject, science information is being continually expanded and updated, so ongoing professional development is important. The challenge to schools and districts usually varies by grade level.

High school science teachers should have a secondary science teaching credential. However, a science "major" can, for example, be well-educated in biology but not-at-all well acquainted with basic physics principles. The resumes of prospective science teachers should be screened in detail to determine that their education, which may also include in-depth professional development or work experience, clearly qualifies them to teach specific science topics.

Middle-school science teachers can often have a secondary science credential or a K-8 or middle school credential for "self-contained" classrooms or all subjects. Elementary teachers with self-contained classrooms are all expected to teach science and few have taken any college science classes. The responsibility for providing adequate content knowledge background then falls to the school, district, or teachers themselves. Professional development offerings must specifically prepare teachers to understand the content of the topics they are required to teach.

Preparation in content knowledge is necessary, but not sufficient. A teacher must also be familiar with how students learn science, and how to be a facilitator of learning. A good science teacher knows how to design classroom experiences to help students construct their own understanding, handle questions in a manner that promotes active learning, and vary instructional techniques to benefit the learning styles of more students.

A. **Teachers are certified for the classes they are teaching.**

B. **.Teacher evaluations support the effective implementation of the science curriculum.**

C. **Instructional coaching ensures continual professional development in implementing best practices in science instruction.** *("Instructional coaching" as used here, describes a role which can be played by a principal, mentor, grade-level group, resource teacher, as well as a staff member whose title is instructional coach.)*

Standard 13: ENGAGED COMMUNITY
Parents and the community receive frequent communications and opportunities to participate in goal setting, instructional support, and program evaluation.

Discussions on science education's quality and the possible effects on the United States' competitive potential in the global scientific community and economy have been held in Congress and neighborhoods for decades. Each community's perspective has a local flavor, due to the experiences of local scientific and technical industries, universities and businesses. An exemplary science education program will reflect the community's concerns in developing and implementing the science program. Consistent two-way communications will benefit the program in building support for the program and benefit members of the community in understanding the rationale behind innovations in science education.

Members of the community often play important roles in the professional development of science teachers, as well as in helping students connect their science studies with community problems and applications. Exemplary science programs enjoy community support for the necessary resources because the community is well-informed about what is taking place in the schools, approves and is proud of the accomplishments of students and teachers, and knows what is needed to maintain the program. This level of positive engagement requires continual effort and collaboration.

A. **Parents and other community members receive frequent communications about the science program.**

B. **Parents and other community members participate as advisors to the science program.**

C. **Parents and other volunteers support science instruction through a variety of roles.**

Key Resources:

- Community collaboration is a recurring theme in NSTA journals, and a search of the website at www.nsta.org will yield many varied articles. Examples will cover a wide range, from teacher professional development to classroom volunteers to student research and more.
- A great resource on student-scientist partnerships is a report from an invitational conference which drew lessons from existing student and scientist partnerships, suggested solutions to barriers that hinder wider use of such partnerships, and recommended ways to interest more scientists and educators. Although somewhat dated (1996) in the programs described, it provides excellent advice and models. The report can be found at http://ssp.terc.edu/conf_rep.htm, and is entitled *National Conference on Student & Scientist Partnerships: Conference Report.*
- United States Department of Education (2007) *Giving Parents Options: Strategies for Informing Parents and Implementing Public School Choice and Supplemental Educational Services Under "No Child Left Behind."* Jessup, MD: ED Pubs. Available online at http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/33/c3/a6.pdf
- Written for teachers planning science learning experiences around community resources: Robertson, W. (2001) *Building successful partnerships: Community connections for science education.* Arlington, VA: NSTA Press.
- Learn more about links between certain parent/community roles in schools and student achievement in: Marzano, R., Waters, T. & McNulty, B. (2005) *School leadership that works: From research to results.* Alexandria, VA: Association for Supervision and Curriculum Development.
- Funding for community partnerships often combines grant funds with commitments from community institutions to provide services to schools. Private foundations can fund these endeavors, and much of the national funding has come through the National Science Foundation, the National Institutes of Health and the U.S. Department of Education. Their websites, as well as "grant opportunities watch" publications are valuable in discovering current opportunities.

Standard 14: DATA-DRIVEN DECISION MAKING
Assessment/evaluation data are used to improve the science program

Why are you doing that? Is it working? Whether examining curriculum, instruction, assessment or community involvement, the most convincing answer will have data behind it. Data about needs, present status, or progress over time will help make the case for taking action and determining priorities for time, money and human resources.

Using data to make decisions may seem obvious, but before glossing over this standard, take the opportunities to examine the school or district culture. What data is required for teacher and administrator evaluations? How much time in staff meetings is spent in discussions featuring far more opinion than data? Are the students' victories and struggles in learning science becoming better known? Leadership must model and insist on using data throughout the system, and aligning data collection with the goals and plans outlined in Standards 1,2, and 5.

In addition to measuring progress toward goals in all areas of the science program, be prepared to cast a wide net. Along with student assessment data, attend to student attitudes and opinions, teachers' perceptions and changing needs, and the thoughts and concerns of parents and other community members.

A. The school and district professional culture values the use of data to inform decision-making.

B. Data from summative assessments is collected, analyzed, and used to make decisions to improve the science program.

Key Resources:

- A comprehensive resource can be found in: Love, N. (2004) *Using data/getting results: A practical guide for school improvement in mathematics and science.* Norwood, MA: Christopher-Gordon Publishers. A figure on page 15 of this book describing the phases of collaborative inquiry provides a terse overview of the processes.
- This research brief describes the data-use practices of six school districts that achieved exemplary results: Education Commission of the States (2002). *No child left behind issue brief: data-driven decision making. Retrieved from http://www.ecs.org/clearinghouse/35/52/3552.pdf*
- For facilitation of professional development in data-driven decision making, see: http://www.ncrel.org/datause/dataprimer/overview.php where a "Data Primer" is organized around four modules: (1) Where are we? (2) Where do we want to go? (3) How fast are we moving and in what direction? (4) Are we leaving anyone behind?
- Another helpful guide is: Learning Points Associates. (Dec. 2004) *Guide to using data in school improvement efforts.* Naperville, IL: author. Available at http://www.learningpt.org/pdfs/datause/guidebook.pdf. Among other good qualities, this guide is useful in identifying all the types of data that have been found to be valuable.

Standard 15: RESULTS
Indicators of student success are positive and improving

"Improvement" of science education has been going on for a long time. Will it ever be finished? Every community's values should be reflected in the discussions about and the answer to this question. Some communities may place more emphasis on higher enrollment in science classes, some on closing achievement gaps, and others on expanding advanced placement and honors classes. But all school districts are required by federal or state laws to collect some data on student achievement. And these data need to show that students are indeed learning.

In the rubrics below, some fairly arbitrary "cut points" are offered, such as 75% of students being proficient on standardized science tests to be rated *basics in place*. While the delineations can be debated or adjusted, the bottom line is that measures of student learning must be markedly positive and aggressively approaching the point where all students are successfully engaged in learning a comprehensive science curriculum

A. Assessment data indicate students are succeeding in understanding science, and any achievement gaps are narrowing.

B. Assessment data, over time, indicate more students are succeeding in understanding science than in previous years.

C. More students are enrolling in elective science classes and otherwise expressing interest in studying science.

Key Resources

- The goals of "No Child Left Behind" federal legislation under President George W. Bush include *all* students being proficient in mastering standards in science and other subjects by 2014, States have been required to submit plans and institute consequences for schools that do not meet planned benchmarks. For more on local pacing plans, see websites of state departments of education and www.ed.gov

- For historical perspective on reform in American schools, as well as broad advice on key elements, see Tyack, L. & Cuban. (1997) *Tinkering toward utopia: a century of public school reform.* Cambridge, MA: Harvard University Press.
- Some straight talk about the value of standardized test scores in improving education outcomes can be found in: Stiggins, R. (October 17, 2007) *Five assessment myths and their consequences.* Education Week. Online at http://www.edweek.org/ew/articles/2007/10/17/08stiggins.h27.html?tmp=25019749