2003

Standards for Science Teacher Preparation

National Science Teachers Association

NSTA Revision Task Force

Steven W. Gilbert, Virginia Polytech. Inst. and State Univ., Falls Church, VA, **Chair**

Patricia Colbert-Cormier, Lafayette High School, Lafayette, LA
George Dewey, Chantilly High School, Chantilly, VA
Julie Gess-Newsome, Northern Arizona University, Flagstaff, AZ
Vincent Lunetta, Pennsylvania State University, State College, PA
Cheryl L. Mason, San Diego State University, San Diego, CA
Maureen McMahon, California State University, Long Beach, Long Beach, CA
Jon Pedersen, The University of Oklahoma, Norman, OK
Dwight Sieggreen, Hillside Middle School, Northville, MI

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Introduction

Any project intending to write education standards for national dissemination and implementation is immediately confronted with the fact that education is a state function, and that the fifty states, plus Puerto Rico, each have their own ideas about what should be taught to their children. Education, unlike many professions, is a highly political act: parents and guardians are concerned about what their children are taught; and various stakeholders have their own ideas about what constitutes a good education. Whether or not they are directly engaged in setting standards, they want to know why a particular set of standards has been selected by those entrusted with their children. Similarly, regulatory agencies and educational institutions must understand why a particular set of standards has been chosen by the science education community to underlie the preparation of science teachers.

The National Science Teachers Association (NSTA) Standards for Science Teacher Preparation are based upon a review of the professional literature and on the goals and framework for science education set forth in the National Science Education Standards (NSES) (National Research Council [NRC], 1996). The NSES is a visionary framework for science teaching in precollege education, based upon the assumption that scientific literacy for citizenship should be a primary—if not exclusive—goal of science education at the precollege level.

In the broadest sense, scientifically literate citizens understand the subject matter of science, but also know and understand the evidence behind the major concepts of science, how such evidence was obtained and why it has been accepted. They are able, for example, to distinguish between science as a process of investigation and technology as a process of design.

Scientifically literate citizens know the difference between scientific and nonscientific knowledge; they understand that useful knowledge need not always be scientific, but that scientific knowledge is valued because it is productive in our interactions with the physical world. They use scientific approaches for analyzing and solving problems requiring investigation, basing their judgments upon evidence rather than presuppositions and bias. They understand how science affects their communities and their lives, and can distinguish productive from nonproductive science. They understand that science is not always intended to produce immediate tangible benefits.

The NSTA Standards for Science Teacher Preparation are consistent with this vision of the NSES. Teachers of science at all grade levels must demonstrate competencies consistent with the achievement of this vision. They should not only demonstrate that they have the necessary knowledge and planning skills to achieve these goals; but also that they are successful in engaging their students in studies of such topics as the relationship of science and technology, nature of science, inquiry in science and science-related issues.

These NSTA standards are intended as the foundation for a performance assessment system, through which teacher candidates must satisfactorily demonstrate their knowledge and abilities at stable assessment points—gateways—in the science teacher preparation program. The standards address the knowledge, skills and dispositions that are deemed important by the National Science Teachers Association for teachers in the field of science. They are fully aligned with the National Science Education Standards and consistent with the standards of the National

Board for Professional Teaching Standards (NBPTS) and the Interstate New Teachers Assessment and Support Consortium (INTASC).

Changes from the 1998 Standards

These standards incorporate a number of changes from the 1998 version. These changes have come about to remedy weaknesses in the standards discovered in their use by the NSTA's NCATE Program Review Board and to address concerns about the vagueness of some of the 1998 standards.

In NCATE institutional reviews, the review board quickly learned that the ten standards adopted in 1998 were too broad to be addressed effectively by institutions, who interpreted the standards in many—sometimes unintended—ways. As an interim measure, NSTA integrated more specific "dimensions," into NCATE program review materials to help institutions understand the meaning of each standard. The dimensions thus became a de facto subset of standards to which programs seeking recognition were required to respond. In this revision, the task force has formally incorporated the dimensions into the standards, refining them in language and placement in order to define the knowledge, skills or dispositions sought for each of the original ten standards better. The standards themselves—especially standards two, three, four, seven and nine—have also been rewritten to focus and clarify their meanings.

The task force has also added a set of subject matter content recommendations to this version of the standards. In the 1998 standards, the content recommendations were similar to those found in the 1987 curriculum-based standards. In addition, the National Science Education Standards were not directly referred to in the 1998 standards; references were added later in NCATE documents. In this revision, content recommendations have been created by the task force based on the recommendations of the American Association of Physics Teachers, the American Chemical Society, the National Association of Biology Teachers and the National Earth Science Teachers Association, and review of the NSES. These recommendations are expressed in the form of competencies rather than courses, and are intended to guide institutions and states in their selection of their subject matter requirements and assessments.

The vision and recommendations of the NSES are given more prominence in this version of the standards than in the previous version. The unifying concepts, for example, have been given more attention, and their meanings have been delineated much more carefully.

In terms of the format of the standards, the revised standards are each followed by a "discussion" section—replacing the "rationale" in the 1998 standards—and an "application to programs" section—replacing the former "recommendations" section. Narratives in these new sections are tighter and more focused than in the previous document. The "indicators" sections in the 1998 version were dropped, since they proved more confusing than helpful in practice.

The revised standards have been subjective to numerous reviews, and comments received from science teacher educators have been carefully examined for possible incorporation into the standards. This version of the standards has generally been positively received and the clarifications welcomed by institutional representatives who have responded to solicitations for input from the NSTA task force.

NSTA Standards for Science Teacher Preparation

Standard 1: Content

Teachers of science understand and can articulate the knowledge and practices of contemporary science. They can interrelate and interpret important concepts, ideas, and applications in their fields of licensure; and can conduct scientific investigations. To show that they are prepared in content, teachers of science must demonstrate that they:

a. Understand and can successfully convey to students the major concepts, principles, theories, laws, and interrelationships of their fields of licensure and supporting fields as recommended by the National Science Teachers Association.

b. Understand and can successfully convey to students the unifying concepts of science delineated by the National Science Education Standards.

c. Understand and can successfully convey to students important personal and technological applications of science in their fields of licensure.

d. Understand research and can successfully design, conduct, report and evaluate investigations in science.

e. Understand and can successfully use mathematics to process and report data, and solve problems, in their field(s) of licensure.

Discussion

The desirability of a strong content background for science teachers is widely recognized and generally accepted, even while it is generally recognized within the professional community that science content expertise alone is not sufficient to define a good teacher. In this standard, *content* is operationally defined to include the knowledge and skills that are learned, or should be learned, in the course of the teacher’s science curriculum. This includes important scientific concepts and relationships, applications of science in technological contexts, mathematical skills and applications, and methods and processes of conducting true scientific investigations. Other knowledge and skills such as those specifically identified in standards related to the nature of science, issues, and community might also be addressed in science content preparation, but are delineated into separate clusters for emphasis.

The National Science Education Standards and Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1993) strongly emphasize all of the dimensions of preparation called for in this cluster of standards. The previous version of these standards did not contain specific recommendations on content, except those carried over from the curriculum standards that preceded them. This set of standards contains specific recommendations for content preparation.

They are based upon discipline-specific recommendations of the American Association of Physics Teachers, the American Chemical Society, the National Association of Biology Teachers and the National Earth Science Teachers Association. Their recommendations were integrated by the NSTA task force with those of the NSES as a basis for the recommendations in this document.

Because an increasing number of states and most members of the science education community have accepted the NSES as a framework document, the NSTA standards and recommendations for teacher preparation are intended as a framework for the preparation of teachers to work effectively in school systems with a science curriculum based on the NSES or professional standards with similar goals.

The rationales for three of the five content standards (subject matter, unifying concepts, and technology/applications [standards 1-3]) have been discussed at length in the NSES. Knowledge of research within the content discipline is required as the basis for conducting instruction through inquiry and engaging students in effective inquiry, as required by standards in the Inquiry cluster. Requirements for mathematics are based on the need for candidates, as teachers, to lead students in the use of mathematics to solve problems and to process, present and interpret data.

The recommendations distinguish between the needs of elementary generalists, elementary-middle level general science teachers, and secondary science teachers in the four traditional disciplines. For the secondary level, core competencies are identified that should be required of any candidate licensed to teach in that discipline. Advanced competencies are identified for specialists in the discipline. Recommendations for multi-field licensure programs and composite teaching fields are also provided.

Applications in Programs

Until recently, the science content for many teachers consisted largely of lecture and validation labs (Boyer, 1987; Dunkin & Barnes, 1986; Smith & Anderson, 1984), with little attention given to undergraduate research experiences or applications of science in technological contexts. Consequently, teacher candidates with majors in the field frequently could not effectively interrelate concepts in their disciplines (Lederman, Gess-Newsome & Latz (1994); Mason, 1992).

While these standards are intended as the framework for a performance-based teacher preparation program, there is a strong argument to be made that they, along with preparation standards under the nature of science, inquiry, and issues clusters, outline much of what should be known by any undergraduate science major.

Regardless of where preparation occurs, the science teacher education program has responsibility for demonstrating that candidates are prepared in relation to these standards and to the content recommendations. *However, NSTA does not require gateway performance data for the recommendations as it does for each of the standards.* The recommendations are presented as a basis for decision-making on course requirements and content in the program and to outline desired content-related competencies that graduates should demonstrate prior to licensure.

Graduate and Postbaccalaureate programs that do not control the content preparation of their candidates may need to prepare an admissions checklist and require deficiency work to ensure that candidates from other programs have the knowledge and skills required to meet these standards.

While standards must be addressed individually, the content recommendations may be addressed in clusters; for example, the unifying concepts may be dealt with together at one or two gateway assessment points. Related conceptual topics may be addressed in a particular course, from which a grade is used as an indicator of preparation. It is up to the program to demonstrate that it has accounted for all of the recommendations associated with this cluster of standards by showing where and how they are addressed.

As a practical matter, course grades may be used as performance indicators in relation to general subject matter preparation, which is the substance of standard one, or where a course specifically addresses the standard such that completing it successfully addresses the standard on its face; for example, a course in research design might meet standard four. The more specific standards (two through five) generally require more specifically targeted assessments.

The number of assessments required for any given standard depends upon the alignment of the assessment tool with the standard, i.e., how valid it is as an indicator. GPA, for example, is a rough indicator and must be supported by other data such as test results and cooperating teacher observations. Results of state mandated tests of content knowledge MUST be reported to the NSTA.

Standards 1 - 3 also require evidence that candidates can effectively convey the content to students. A number of approaches may be used to ensure that this occurs, but it is imperative that student performance, i.e., the actual impact of candidate performance on student understanding or achievement, is taken into account when determining and reporting the effectiveness of the candidate in conveying knowledge. Other measures may be included to provide supporting data, such as candidate reflections on their videotaped performance, using an assessment rubric; student feedback ratings; case write-ups demonstrating where knowledge has been effectively conveyed; and cooperating teacher and supervisor observations using well-defined criteria.

Science Content Recommendations

A. Recommendations for Elementary Generalists

A.1. Elementary teachers without a science specialization should be prepared to teach science with a strong emphasis on observation and description of events, manipulation of objects and systems, and identification of patterns in nature across subjects. They should be prepared to effectively engage students in concrete manipulative activities that will lead to the development of desired concepts through investigation and analysis of experience. Elementary generalists should be prepared to lead students to understand the unifying concepts of science, including:

1. Multiple ways we organize our perceptions of the world and how systems organize the studies and knowledge of science.
2. Nature of scientific evidence and the use of models for explanation.
3. Measurement as a way of knowing and organizing observations of constancy and change.
4. Evolution of natural systems and factors that result in evolution or equilibrium.

5. Interrelationships of form, function, and behaviors in living and nonliving systems.

A.2. At the elementary level in particular, the sciences should be interwoven to develop interdisciplinary perspectives. In relation to biology, elementary generalists should be prepared to lead students to understand:

6. Features distinguishing living from nonliving systems.
7. Characteristics distinguishing plants, animals, and other living things.
8. Multiple ways to order and classify living things.
9. Ways organisms function and depend on their environments
10. Ways organisms are interdependent.
11. Reproductive patterns and life cycles of common organisms.
12. Growth, change, and interactions of populations to form communities.

A.3. In the physical sciences, elementary generalists should be prepared to lead students to understand:

13. Properties of matter such as mass, solubility, and density.
14. Combinations of matter to form solutions, mixtures, and compounds with different properties.
15. Variations in the physical and chemical states of matter and changes among states.
16. Ordering and classification of matter and energy and their behaviors.
17. Factors affecting the position, motion and behavior of objects.
18. Properties of simple machines and tools, such as levers and screws.
19. Properties of light, electricity, sound, and magnetism.
20. Types of energy, energy sources, and simple transformations of energy.

A.4. In the Earth and space sciences, elementary generalists should be prepared to lead students to understand:

21. Natural objects in the sky and why they change in position and appearance.
22. Causes of the seasons and seasonal changes.
23. Changes in the atmosphere resulting in weather and climate.
24. Changes in the Earth creating and eroding landforms.
25. Basic properties of rocks, minerals, water, air, and energy.
26. Differences between renewable and nonrenewable natural resources.

A.5. To create interdisciplinary perspectives and to help students understand why science is important to them, elementary generalists should be prepared to lead students to understand:

27. Differences between science, as investigation, and technology as design.
28. Impact of science and technology on themselves and their community, and on personal and community health.
29. How to use observation, experimentation, data collection, and inference to test ideas and construct concepts scientifically.
30. How to use metric measurement and mathematics for estimating and calculating, collecting and transforming data, modeling, and presenting results.

B. Recommendations for Elementary and Middle Level General Science Teachers

B.1. Elementary and middle level general science specialists should be prepared with a strong emphasis on collaborative inquiry in the laboratory and field. They should have a deeper understanding of the field than generalists, but should have the same thematic and interdisciplinary perspective on science. To achieve this, science specialists at this level should have all of the competencies described for the elementary generalist, but also should be prepared in biology to lead students to understand:

1. Factors governing the structures, functions, and behaviors of living systems.
2. Multiple systems of classification of organisms.
3. Cycles of matter, and flow of energy, through living and nonliving pathways.
4. Natural selection, adaptation, diversity, and speciation.
5. Structure, function, and reproduction of cells, including microorganisms.
6. Levels of organization from cells to biomes.
7. Reproduction and heredity, including human reproduction and contraception.
8. Behavior of living systems and the role of feedback in their regulation.
9. Hazards related to living things including allergies, poisons, disease, and aggression.

B.2. In relation to the physical sciences, science specialists at this level should have all of the competencies described for the elementary generalist, but also should be prepared in chemistry and physics to lead students to understand:

10. Properties and applications of sound, light, magnetism, and electricity.
11. Potential and kinetic energies and concepts of work.
12. Energy flow in physical and chemical systems, including simple machines
13. States of matter and bonding in relation to molecular behavior and energy.
14. Conservation of matter and energy.
15. Classifications of elements and compounds.

16. Solvents (especially water) and solutions.
17. Chemical nature of the earth and its living organisms.
18. Nature of radioactive substances.
19. Chemical, electrical and radiation hazards.

B.3. In the Earth and space sciences, science specialists at this level should have all of the competencies described for the elementary generalist, but also should prepared in the Earth and space sciences to lead students to understand:

20. Structures of objects and systems in space.
21. Earth's structure, evolution, history, and place in the solar system.
22. Characteristics and importance of oceans, lakes, rivers, and the water cycle.
23. Characteristics of the atmosphere including weather and climate.
24. Changes in the Earth caused by chemical, physical, and biological forces.
25. Causes and occurrences of hazards such as tornados, hurricanes, and earthquakes.
26. Characteristics and importance of cycles of matter such as oxygen, carbon, and nitrogen.
27. Characteristics of renewable and nonrenewable natural resources and implications for their use.
28. Interactions among populations, resources, and environments.

B.4. To create interdisciplinary perspectives and to help students understand why science is important to them, elementary/middle level science specialists should have all of the competencies described for the elementary generalist, but also should be prepared to lead students to understand:

29. Interrelationships of pure and applied sciences, and technology.
30. Applications of science to local and regional problems and the relationship of science to one's personal health, well-being, and safety.
31. Historical development and perspectives on science including contributions of underrepresented groups and the evolution of major ideas and theories.
32. Applications of science to the investigation of individual and community problems.
33. Use of technological tools in science, including calculators and computers.
34. Applications of basic statistics and statistical interpretation to the analysis of data.

C. Recommendations for Secondary Science Teachers

C.1. Recommendations for All Secondary Science Teachers

Secondary teachers are generally prepared with more depth in the content of a given field than are teachers of younger students. The major divisions of the natural sciences are biology, chemistry, the Earth and space sciences, and physics. All teachers licensed in a given discipline should know, understand, and teach with the breadth of understanding reflected in the core competencies for that discipline. Specialists in a discipline should also have achieved the advanced competencies for that discipline. All secondary teachers should also be prepared to lead students to understand the unifying concepts of science including:

1. Multiple ways we organize our perceptions of the world and how systems organize the studies and knowledge of science.
2. Nature of scientific evidence and the use of models for explanation.
3. Measurement as a way of knowing and organizing observations of constancy and change.
4. Evolution of natural systems and factors that result in evolution or equilibrium.
5. Interrelationships of form, function, and behaviors in living and nonliving systems.

C.2. Recommendations for Teachers of Biology

C.2.a. *Core Competencies*. All teachers of biology should be prepared to lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:

1. Life processes in living systems including organization of matter and energy.
2. Similarities and differences among animals, plants, fungi, microorganisms, and viruses.
3. Principles and practices of biological classification.
4. Scientific theory and principles of biological evolution.
5. Ecological systems including the interrelationships and dependencies of organisms with each other and their environments.
6. Population dynamics and the impact of population on its environment.
7. General concepts of genetics and heredity.
8. Organization and functions of cells and multicellular systems.
9. Behavior of organisms and their relationships to social systems.
10. Regulation of biological systems including homeostatic mechanisms.
11. Fundamental processes of modeling and investigating in the biological sciences.
12. Applications of biology in environmental quality and in personal and community health.

C.2.b. *Advanced Competencies.* In addition to these core competencies, teachers of biology as a primary field should be prepared to effectively lead students to understand:

13. Bioenergetics including major biochemical pathways.
14. Biochemical interactions of organisms with their environments.
15. Molecular genetics and heredity and mechanisms of genetic modification.
16. Molecular basis for evolutionary theory and classification.
17. Causes, characteristics and avoidance of viral, bacterial, and parasitic diseases.
18. Issues related to living systems such as genetic modification, uses of biotechnology, cloning, and pollution from farming.
19. Historical development and perspectives in biology including contributions of significant figures and underrepresented groups, and the evolution of theories in biology.
20. How to design, conduct, and report research in biology.
21. Applications of biology and biotechnology in society, business, industry, and health fields.

C.2.c. *Supporting Competencies.* All teachers of biology should also be prepared to effectively apply concepts from other sciences and mathematics to the teaching of biology including basic concepts of:

22. Chemistry, including general chemistry and biochemistry with basic laboratory techniques.
23. Physics including light, sound, optics, electricity, energy and order, magnetism, and thermodynamics.
24. Earth and space sciences including energy and geochemical cycles, climate, oceans, weather, natural resources, and changes in the Earth.
25. Mathematics, including probability and statistics.

C.3. <u>Recommendations for Teachers of Chemistry</u>

C.3.a. *Core Competencies*. All teachers of chemistry should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:

1. Fundamental structures of atoms and molecules.
2. Basic principles of ionic, covalent, and metallic bonding.
3. Physical and chemical properties and classification of elements including periodicity.
4. Chemical kinetics and thermodynamics.
5. Principles of electrochemistry.
6. Mole concept, stoichiometry, and laws of composition.

7. Transition elements and coordination compounds.
8. Acids and bases, oxidation-reduction chemistry, and solutions.
9. Fundamental biochemistry.
10. Functional and polyfunctional group chemistry.
11. Environmental and atmospheric chemistry.
12. Fundamental processes of investigating in chemistry.
13. Applications of chemistry in personal and community health and environmental quality.

C.3.b. *Advanced Competencies.* In addition to the core competencies, teachers of chemistry as a primary field should also be prepared to effectively lead students to understand:

14. Molecular orbital theory, aromaticity, metallic and ionic structures, and correlation to properties of matter.
15. Superconductors and principles of metallurgy.
16. Advanced concepts of chemical kinetics, and thermodynamics.
17. Lewis adducts and coordination compounds.
18. Solutions, colloids, and colligative properties.
19. Major biological compounds and natural products.
20. Solvent system concepts including non-aqueous solvents.
21. Chemical reactivity and molecular structure including electronic and steric effects.
22. Organic synthesis and organic reaction mechanisms.
23. Energy flow through chemical systems.
24. Issues related to chemistry including ground water pollution, disposal of plastics, and development of alternative fuels.
25. Historical development and perspectives in chemistry including contributions of significant figures and underrepresented groups, and the evolution of theories in chemistry.
26. How to design, conduct, and report research in chemistry.
27. Applications of chemistry and chemical technology in society, business, industry, and health fields.

C.3.c. *Supporting Competencies*. All teachers of chemistry should be prepared to effectively apply concepts from other sciences and mathematics to the teaching of chemistry including:

28. Biology, including molecular biology, bioenergetics, and ecology.
29. Earth science, including geochemistry, cycles of matter, and energetics of Earth systems.

30. Physics, including energy, stellar evolution, properties and functions of waves, motions and forces, electricity, and magnetism.
31. Mathematical and statistical concepts and skills including statistics and the use of differential equations and calculus.

C.4. Recommendations for Teachers of the Earth and Space Sciences

C.4.a. *Core Competencies*. All teachers of the Earth and space sciences should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:

1. Characteristics of land, atmosphere, and ocean systems on Earth.
2. Properties, measurement, and classification of Earth materials.
3. Changes in the Earth including land formation and erosion.
4. Geochemical cycles including biotic and abiotic systems.
5. Energy flow and transformation in Earth systems.
6. Hydrological features of the Earth.
7. Patterns and changes in the atmosphere, weather, and climate.
8. Origin, evolution, and planetary behaviors of Earth.
9. Origin, evolution, and properties of the universe.
10. Fundamental processes of investigating in the Earth and space sciences.
11. Sources and limits of natural resources.
12. Applications of Earth and space sciences to environmental quality and to personal and community health and welfare.

C.4.b. *Advanced Competencies.* In addition to the core competencies, teachers of the Earth and space sciences as a primary field should be prepared to effectively lead students to understand:

13. Gradual and catastrophic changes in the Earth.
14. Oceans and their relationship to changes in atmosphere and climate.
15. Hydrological cycles and problems of distribution and use of water.
16. Dating of the Earth and other objects in the universe.
17. Structures and interactions of energy and matter in the universe.
18. Impact of changes in the Earth on the evolution and distribution of living things.
19. Issues related to changes in Earth systems such as global climate change, mine subsidence, and channeling of waterways.

20. Historical development and perspectives in the Earth and space sciences, including contributions of significant figures and underrepresented groups, and the evolution of theories in these fields.
21. How to design, conduct, and report research in the Earth and space sciences.
22. Applications of the Earth and space sciences and related technologies in society, business, industry, and health fields.

C.4.c. *Supporting Competencies*. All teachers of Earth and space sciences should be prepared to effectively apply concepts from other sciences and mathematics to the teaching of Earth and space sciences including concepts of:

23. Biology, including evolution, ecology, population dynamics, and the flow of energy and materials through Earth systems.
24. Chemistry, including broad concepts and basic laboratory techniques of inorganic and organic chemistry, physical chemistry, and biochemistry.
25. Physics, including electricity, forces and motion, energy, magnetism, thermodynamics, optics, and sound; as well as basic quantum theory.
26. Mathematics, including statistics and probability.

C.5. <u>Recommendations for Teachers of Physics</u>

C.5.a. *Core Competencies*. All teachers of physics should be prepared lead students to understand the unifying concepts required of all teachers of science, and should in addition be prepared to lead students to understand:

1. Energy, work, and power.
2. Motion, major forces, and momentum.
3. Newtonian principles and laws including engineering applications.
4. Conservation of mass, momentum, energy, and charge.
5. Physical properties of matter.
6. Kinetic-molecular motion and atomic models.
7. Radioactivity, nuclear reactors, fission, and fusion.
8. Wave theory, sound, light, the electromagnetic spectrum and optics.
9. Electricity and magnetism
10. Fundamental processes of investigating in physics.
11. Applications of physics in environmental quality and to personal and community health.

C.5.b. *Advanced Competencies.* In addition to the core competencies, teachers of physics as a primary field should be prepared to effectively lead students to understand:

12. Thermodynamics and relationships between energy and matter.
13. Nuclear physics including matter-energy duality and reactivity.
14. Angular rotation and momentum, centripetal forces, and vector analysis.
15. Quantum mechanics, space-time relationships, and special relativity.
16. Models of nuclear and subatomic structures and behavior.
17. Light behavior, including wave-particle duality and models.
18. Electrical phenomena including electric fields, vector analysis, energy, potential, capacitance, and inductance.
19. Issues related to physics such as disposal of nuclear waste, light pollution, shielding communication systems and weapons development.
20. Historical development and cosmological perspectives in physics including contributions of significant figures and underrepresented groups, and evolution of theories in physics.
21. How to design, conduct, and report research in physics.
22. Applications of physics and engineering in society, business, industry, and health fields.

C.5.c. *Supporting Competencies*. All teachers of physics should be prepared to effectively apply concepts from other sciences and mathematics to the teaching of physics including concepts of:

23. Biology, including organization of life, bioenergetics, biomechanics, and cycles of matter.
24. Chemistry, including organization of matter and energy, electrochemistry, thermodynamics, and bonding.
25. Earth sciences or astronomy related to structure of the universe, energy, and interactions of matter.
26. Mathematical and statistical concepts and skills including statistics and the use of differential equations and calculus.

D. Recommended Program Requirements

When teachers are prepared to teach specific composite courses labeled physical science or general science, they should have at least core competencies in the primary disciplines comprising the composite course. Teachers in traditional disciplines (biology, chemistry, Earth and space sciences, or physics) are generally prepared in one of three ways:

1. Single field programs, which require specialization (often a major) in a primary discipline, with less preparation in a second discipline. In this case, the teacher should have advanced competencies in the primary discipline and at least core competencies in the second discipline, with supporting competencies in the remaining sciences.

2. Dual field programs, which require equal preparation in two disciplines, usually with less than a major in each. In this case, teachers should have advanced competencies in both disciplines, with supporting competencies in the remaining two disciplines.
3. Broad field programs, which require preparation in three or four disciplines at once, with licensure in each discipline. In this case, teachers should have advanced competencies in one discipline and core competencies in the remaining disciplines.

Preparation of middle school teachers as general science teachers (following National Middle School Association recommendations) should follow the specific middle school standards recommended in section 2, rather than the subject-specific secondary standards. Such programs are generally for middle level specifically, or are designed for elementary teachers who wish to be certified in middle level science.

Standard 2: Nature of Science

Teachers of science engage students effectively in studies of the history, philosophy, and practice of science. They enable students to distinguish science from nonscience, understand the evolution and practice of science as a human endeavor, and critically analyze assertions made in the name of science. To show they are prepared to teach the nature of science, teachers of science must demonstrate that they:

a. Understand the historical and cultural development of science and the evolution of knowledge in their discipline.

b. Understand the philosophical tenets, assumptions, goals, and values that distinguish science from technology and from other ways of knowing the world.

c. Engage students successfully in studies of the nature of science including, when possible, the critical analysis of false or doubtful assertions made in the name of science.

Discussion

Understanding of the nature of science—the goals, values and assumptions inherent in the development and interpretation of scientific knowledge (Lederman, 1992)—has been an objective of science instruction since at least the turn of the last century (Central Association of Science and Mathematics Teachers, 1907). It is regarded in contemporary documents as a fundamental attribute of science literacy (AAAS, 1993; NRC, 1996) and a defense against unquestioning acceptance of pseudoscience and of reported research (Park, 2000; Sagan, 1996). Knowledge of the nature of science can enable individuals to make more informed decisions with respect to scientifically based issues; promote students' in-depth understandings of "traditional" science subject matter; and help them distinguish science from other ways of knowing (Lederman, personal communication).

An important purpose of pre-college science education is to educate individuals who can make valid judgments on the value of knowledge created by science and other ways of knowing, and to understand why the literature regards scientific knowledge not as absolute, but as tentative, empirically based, culturally embedded, and the product of some degree of assumption, subjectivity, creativity, and inference (Lederman & Niess, 1997).

Research clearly shows most students and teachers do not adequately understand the nature of science. For example, most teachers and students believe that all scientific investigations adhere to an identical set of steps known as the scientific method (McComas, 1996), and that theories are simply immature laws (Horner & Rubba, 1979). Even when teachers understand and support the need top include the nature of science in their instruction, they do not always do so (Lederman, 1992). Instead they may rely upon the false assumption that doing inquiry leads to understanding of science (Abd-El-Khalick & Lederman, 2000).

Explicit instruction is needed both to prepare teachers (Abd-El-Khalick & Lederman, 2000) and to lead students to understand the nature of science (Khishfe & Abd-El-Khalick, 2002). Helping teachers to focus on nature of science as an important instructional objective resulted in more explicit nature of science instruction (Lederman, Schwartz, Abd-El-Khalick & Bell, 2001).

Applications in Programs

All students of science, whether teacher candidates or not, should have knowledge of the nature of science as defined in this standard, and should have the skills needed to engage students in the critical analysis of scientific and pseudoscientific claims in an appropriate way.
This requires explicit attention to the nature of science, as defined in this standard, as a part of the preparation of science teachers. Candidates should have multiple opportunities to study and analyze literature related to the history and nature of science, such as The Demon Haunted World (Sagan, 1996); Great Feuds in Science (Hellman, 1998) Facts, Fraud and Fantasy (Goran, 1979) and The Structure of Scientific Revolutions (Kuhn, 1962). In addition, they should be required to analyze, discuss and debate topics and reports in the media related to the nature of science and scientific knowledge in courses and seminars throughout the program, not just in an educational context. Students should engage in active investigation and analysis of the conventions of science as reflected in papers and reports in science, across fields, in order to understand similarities and differences in methods and interpretations in science, and to identify strengths and weaknesses of findings.

Candidates are required to demonstrate that they are effective by successfully engaging students in the study of the nature of science. Assessments with regard to understanding may include such possibilities as completion of independent study courses, seminars or assignments; projects; papers; summative readings; or case study analyses. Assessments of effectiveness must include at least some demonstrably positive student outcomes in studies related to the nature of science as delineated by the standards in this cluster.

Standard 3: Inquiry

Teachers of science engage students both in studies of various methods of scientific inquiry and in active learning through scientific inquiry. They encourage students, individually and collaboratively, to observe, ask questions, design inquiries, and collect and interpret data in order to develop concepts and relationships from empirical experiences. To show that they are prepared to teach through inquiry, teachers of science must demonstrate that they:

a. Understand the processes, tenets, and assumptions of multiple methods of inquiry leading to scientific knowledge.

b. Engage students successfully in developmentally appropriate inquiries that require them to develop concepts and relationships from their observations, data, and inferences in a scientific manner.

Discussion

Reviews of scientific literature demonstrate that scientific inquiry consists of more than a single series of steps called "the scientific method." Scientists may use multiple strategies and processes to solve different kinds of problems. One of the major goals of science education, according to the Benchmarks for Scientific Literacy (AAAS, 1993) and the National Science Education Standards (NRC, 1996) is to enable students to use inquiry to solve problems of interest to them. The ability to engage in effective inquiry using scientifically defensible methods is considered a hallmark of scientific literacy.

True inquiry requires the use of nonalgorithmic and complex higher-order thinking skills to address open-ended problems (Resnick, 1987). Multiple solutions may be possible, and the inquirer must use multiple, sometimes conflicting, criteria to evaluate his or her actions and findings. Inquiry is characterized by a degree of uncertainty about outcomes. True inquiry ends with an elaboration and judgment that depends upon the previous reasoning processes.

In science education, inquiry may take a number of forms: discovery learning, in which the teacher sets up the problem and processes but allows the students to make sense of the outcomes on their own, perhaps with assistance in the form of leading questions; guided inquiry, in which the teacher poses the problem and may assist the students in designing the inquiry and making sense of the outcome; and open inquiry, in which the teacher merely provides the context for solving problems that students then identify and solve (Trowbridge & Bybee, 1990).

These three approaches lie on a continuum without boundaries between them. What is common to all of them is that they require students to solve a genuine (to them) problem by observing and collecting data and constructing inferences from data. More advanced forms of inquiry require students to ask questions that can be addressed by research, design experiments, and evaluate conclusions. Teachers who use inquiry effectively tend to be more indirect, asking more open-ended questions, leading rather than directing, and stimulating more student-to-student discussion (Brophy & Good, 1986). In general, the younger the child, the more concrete the inquiries should be.

Students who learn through inquiry gain a deeper understanding of the resulting concepts than when the same concepts are presented through lecture or readings. This has led to the principle that less is more: Teaching fewer concepts with greater depth will result in better long-term understanding than covering many concepts superficially. In addition, students will gain the skills of inquiry and scientific attitudes desired by the standards, and gain greater knowledge of how scientific research is actually conducted.

Applications in Programs

Candidates in a science teacher preparation program should be provided with multiple opportunities to solve open-ended problems using appropriate scientific methods. These opportunities should be present in their science content courses, but also should be fundamental in their science methods preparation. Many candidates enter teaching because they want to impart knowledge: It is not easy for them to lead students by listening and questioning, and to allow students to infer proposed solutions to problems. Practice is essential.

The preparation of teachers for the elementary level, especially generalists, should require inquiry-based university science courses. Stalheim-Smith and Scharmann (1996) and Stoddart, Connell, Stofflett and Peck (1993) found that the use of constructivist teaching methodologies and learning cycles, methods that are generally inquiry-based, improved the learning of science by candidates in elementary education. Such courses also may increase the confidence level of generalists, who are often not confident in their ability to do science.

Secondary programs should also strongly emphasize inquiry and pay close attention to preparing teachers to effectively lead students in such activities. All programs should provide explicit instruction in the nature of inquiry as well as its applications. Like the nature of science, inquiry is not learned well simply through practice. In general, the term “scientific method” (for the hypothetico-deductive method) should be avoided, since it may lead students to believe there is only one way to conduct scientific inquiries. Inductive studies have played a valuable role in science, as have mathematical and computer modeling. Hypotheses are not used formally by scientists in all research, nor are experiments per se the substance of all research. Candidates should study cases in which different approaches to inquiry are used in science, and should endeavor to communicate such differences to their students.

The role of the teacher is not just to engage students in inquiry in order to develop their conceptual knowledge and process skills, but also to increase their understanding of how scientific inquiries are conducted, and how decisions are made in science. In this regard, the inquiry standards overlap and support the nature of science standards.

Inquiry demands skill in the analysis of data and assessment of results to reach reasonable and valid conclusions. Candidates must be able to demonstrate not only that they know and understand common and different modes of scientific inquiry, but also that they can and do effectively engage students in inquiries. They should be able to demonstrate their effectiveness through student data profiles or similar means that they are effective in conducting such activities.

Standard 4: Issues

Teachers of science recognize that informed citizens must be prepared to make decisions and take action on contemporary science- and technology-related issues of interest to the general society. They require students to conduct inquiries into the factual basis of such issues and to assess possible actions and outcomes based upon their goals and values. To show that they are prepared to engage students in studies of issues related to science, teachers of science must demonstrate that they:

a. Understand socially important issues related to science and technology in their field of licensure, as well as processes used to analyze and make decisions on such issues.

b. Engage students successfully in the analysis of problems, including considerations of risks, costs, and benefits of alternative solutions; relating these to the knowledge, goals and values of the students.

Discussion

An important basic function of science teacher education is to prepare teachers to relate science and technology meaningfully to the local community, to the daily lives of students, and to broader societal issues (AAAS, 1993; NRC, 1996).

Nearly fifty years ago Ralph Tyler argued that subject matter specialists should seek to answer the question: "What can your subject contribute to the education of young people who are not going to be specialists in your field; what can your subject contribute to the layman, the garden variety of citizen?" (Tyler, 1949, p. 26). The response of the science education community today is to identify elements of science instruction that contribute to the science literacy of individuals as citizens

The abilities of students, as citizens, to make justified decisions on values and issues related to science and technology, to understand that there may be many sides to an issue, and that there are always cost-benefit tradeoffs in decision-making, are fundamental components not only of science literacy, but also of citizenship in a democratic society.

Many issues today are related to science and technology. Making a meaningful decision on these issues requires knowledge of related science content, the nature of science and technology, and the ways science relates to oneself and to others in society. Intelligent decision-making on issues requires data and context, or decisions become mere opinions. Science teachers must be prepared to lead students in structured explorations of issues of concern, not just soliciting opinions or conducting debates with little substantive backing.

To that end, programs must provide explicit tools for decision-making and cost-benefit analysis and ensure that candidates are prepared and capable of using these tools in their teaching.

Applications in Programs

Science teacher preparation programs should give explicit attention to the study of socially important issues related to science and technology such as species preservation, land use, chemical pollution, weapons development, and cloning, to name but a few. Such issues may be introduced in science courses, but seldom do science courses provide for structured cost-benefit analyses or decision-making on these issues that considers all perspectives. Programs must ensure that candidates are prepared to lead students in learning how to dissect and analyze issues using data and information as resources.

The question of how to consider an issue is just as important as the issues considered. To that end, candidates will themselves need to learn how to explore issues with an open mind. Once this is accomplished, they will need to learn how to lead students to explore these issues with the goal of making an informed and justified decision.

To meet this standard, candidates must demonstrate that they are aware of important issues and are knowledgeable of approaches to analyzing these issues. Candidates should access common sources of information (newspapers, magazines, televised reports) to relate their science instruction to contemporary issues and events. They must then demonstrate through student achievement that they are able to effectively lead them in the study of an important issue.

Standard 5: General Skills of Teaching

Teachers of science create a community of diverse learners who construct meaning from their science experiences and possess a disposition for further exploration and learning. They use, and can justify, a variety of classroom arrangements, groupings, actions, strategies, and methodologies. To show that they are prepared to create a community of diverse learners, teachers of science must demonstrate that they:

a. Vary their teaching actions, strategies, and methods to promote the development of multiple student skills and levels of understanding.

b. Successfully promote the learning of science by students with different abilities, needs, interests, and backgrounds.

c. Successfully organize and engage students in collaborative learning using different student group learning strategies.

d. Successfully use technological tools, including but not limited to computer technology, to access resources, collect and process data, and facilitate the learning of science.

e. Understand and build effectively upon the prior beliefs, knowledge, experiences, and interests of students.

f. Create and maintain a psychologically and socially safe and supportive learning environment.

Discussion

Science teachers and specialists must provide all students with motivation and opportunities to learn from instruction and make sense of science. A basic assumption of the science standards is that science instruction must address the needs of all students, and that all students can learn science (AAAS, 1989; NRC, 1996). Teachers must be creative decision-makers who adapt and create meaningful activities (Biological Sciences Curriculum Study [BSCS], 1995; Orlich, Harder, Callahan, & Gibson, 1998) with a responsibility to change their practices if necessary in order to help students learn more effectively.

Many factors shape a person's knowledge and perceptions, including life experiences; social, emotional, and cognitive developmental stages (APA, 1992); inherent intelligences (Gardner, 1983); learning styles (Curry, 1990); race and gender; ethnicity and culture (Banks, 1993); and demographic setting (Orlich, et al., 1998). Teachers must consider the influence of these factors, real or potential, on student learning.

Science related instruction should be presented in many ways including, but not limited to, cooperative learning, concept mapping, diagramming, model building, role playing, game-playing, simulating, studying cases, questioning, discussing, solving problems, inquiring, field trips, projects, electronic media, written reporting of investigative techniques and data, and reading.

In general, learning a particular concept should involve multiple interactions with various features of the concept. In turn, concepts must be integrated into a coherent network of concepts from which one can make cogent decisions. Teachers must provide learning opportunities requiring multiple interactions with a concept in different contexts.

Learning occurs within a social context. Science educators must teach students the social processes of consensus building and engage them in the social construction of meaning (Zeidler, 1997). In other words science education, like education in all fields, should encourage students to think about thinking, facilitate creativity and critical judgment, and favor development of self-awareness (APA, 1992; Zeidler, Lederman & Taylor, 1992).

Candidates should know how to use appropriate technology including, but not limited to, computers and computer peripherals, both to enhance learning and to relate the use of technology to science. The ability of students to use technological tools is becoming increasingly important for collecting and processing data; and for presenting and disseminating the results. In addition to using technology in the science classroom, teachers should also ensure that students understand the role technology plays in professional science.

Teachers of science should be able to determine and use presently held student knowledge to frame and develop new concepts to be learned. Much of what we know about how people learn has been encapsulated in the epistemology of constructivism, which holds that "…learners are actively involved in the knowledge construction process by using their existing knowledge to make sense of new experiences"(Marion, Hewson, Tabachnick, & Blomker, 1999, p. 249). Pre-existing knowledge influences the way new knowledge is added to the individual's conceptual model, modifying its subsequent meaning (Stahl, 1991). To be effective, teachers must learn how to listen and to probe for various conceptualizations, and then use this knowledge to frame the way the concepts to be learned are taught.

Applications in Programs

The standards under the general teaching cluster are largely skills based and must be demonstrated by data from the classroom. Not all of the standards require demonstrations of student achievement or performance, but where effectiveness must be demonstrated, data from students should be used.

Programs should provide candidates with ample opportunities to work with students using well-defined indicators of effective pedagogy. Candidates must go beyond demonstrating that they can create varied plans for instruction (as in a methods course) and actually implement a unit that has appropriate variety.

Not all schools have diversity in terms of racial or ethnic makeup, but almost all have variations in socio-economic status, gender and learning styles. Candidates should be able to show how they have considered such differences in their planning and teaching. These considerations may be directed at a group or at individuals. For example, demonstrating the ability to make appropriate provisions for a student who does not speak English well, or who has a defined disability might be acceptable evidence of adapting instruction.

The ability to use structured collaborative learning effectively is an important part of Standard 15. This includes, but goes beyond, setting up effective lab groups. Strategies such as Teams-Games-Tournament (TGT) and Student Teams, Achievement Division (STAD) are examples of alternative ways to organize instruction, where students teach each other (Slavin, 1996).

Technology use is the emphasis of standard 16, as opposed to teaching about technology in contrast with science. The availability of technology in schools may limit the ability of some candidates to demonstrate their performance with students. If a teacher preparation program is situated in an area where computer technology is not common in the schools, it may be necessary to purchase laptops and lab ware for use in the schools.

Pretesting and preconceptions surveys are excellent ways for candidates to determine the prior conceptual knowledge of their students. Candidates should also be able to show how they used prior conceptions and variations in the knowledge of their students to plan instruction in relation to the target concept.

The cooperating teacher, using a rubric designed by the program, may assess classroom atmosphere. The candidate may also collect student feedback using an instrument of his or her own design.

Standard 6: Curriculum

Teachers of science plan and implement an active, coherent, and effective curriculum that is consistent with the goals and recommendations of the National Science Education Standards. They begin with the end in mind and effectively incorporate contemporary practices and resources into their planning and teaching. To show that they are prepared to plan and implement an effective science curriculum, teachers of science must demonstrate that they:

a. Understand the curricular recommendations of the National Science Education Standards, and can identify, access, and/or create resources and activities for science education that are consistent with the standards.

b. Plan and implement internally consistent units of study that address the diverse goals of the National Science Education Standards and the needs and abilities of students.

Discussion

The National Science Education Standards defines curriculum as "the way content is delivered . . . the structure, organization, balance, and presentation of the content in the classroom." (NRC, 1996, p. 2). The Third International Study of Mathematics and Science identifies three major dimensions: the intended curriculum (goals and plans), the implemented curriculum (practices, activities, and institutional arrangements) and the attained curriculum (what students actually achieve through their educational experiences) (Schmidt, et al., 1996a, p. 16). For purposes of this standard, curriculum encompasses the intended and implemented curriculum, Well-prepared science teachers can plan, implement and evaluate a high quality, standards-based science curriculum that includes long-term expectations, learning goals and objectives, plans, activities, materials, and assessments. To do this effectively, a teacher must be familiar with professionally developed national, state, and local standards for science education. They must be able to find and use, adapt, or create materials that are consistent with these standards. Candidates should know how to effectively use various resources such as news media, libraries, resource centers and the Internet.

Units of study, from lesson plans to topical units, to yearlong plans, should be internally consistent and well structured, based upon stated goals achievable through well-articulated activities. They should also be consistent with the ages, interests, and abilities of the students to be taught. The aims of such units should be demonstrably aligned with the National Science Education Standards as well as any other set of standards required of the candidate, and should be shown as well to meet the needs and consider the abilities of students.

Applications in Programs

Teacher candidates should engage in planning and implementing lessons and units of instruction early and often, and should be held responsible for demonstrating such planning throughout the program. With little experience in teaching, candidates may find such planning difficult and time-consuming. There is a tendency among novices to fall back upon activities for their own sake, rather than to deliberately plan a lesson or a unit with concern for how it might be made more effective. Practice in implementing units that have been designed to portray the National Science Education Standards and that have been field-tested may offer an opportunity to practice inquiry based teaching in a supportive context with a high probability of success.

Resource units or collections of related materials are one way candidates can be shown to be familiar with a wide variety of materials in relation to a particular topic. Lesson plans and unit plans are generally required in most programs and can be used as data to verify that the program addresses the standards.

Candidates can be asked to formally assess the internal consistency of their plans using program criteria and may create a reflective narrative to explain that assessment. This assessment may then be returned as part of a portfolio or as an independent assessment and may be used by the program to verify candidate skills in relation to standard 20.

Standards 7: Science in the Community

Teachers of science relate their discipline to their local and regional communities, involving stakeholders and using the individual, institutional, and natural resources of the community in their teaching. They actively engage students in science-related studies or activities related to locally important issues. To show that they are prepared to relate science to the community, teachers of science must demonstrate that they:

a. Identify ways to relate science to the community, involve stakeholders, and use community resources to promote the learning of science.

b. Involve students successfully in activities that relate science to resources and stakeholders in the community or to the resolution of issues important to the community.

Discussion

Community resources can be used to facilitate teaching and help students learn science. It is the teacher's responsibility to identify resources and use them effectively to help students learn. However, teachers often do not know much about the families and communities of their students (Ford, 1993; Nieto, 1992; Patthey-Chavez, 1993; Rivera & Poplin, 1995). They may not reside in the same neighborhoods as their students and so may not know of resources that could help them teach science more effectively. Students may be important contacts for identifying these resources.

The National Science Education Standards call for teachers of science to "identify and use resources outside the school" (NRC, 1996, p.3). Local resources are most important for several reasons, not the least of which is that they are available and relevant. Global resources and issues may seem distant and unrelated to the lives of many students; on the other hand, local resources and issues have a reality in their immediate lives.

Examples of activities may include the involvement of family members in science-related activities or field trips, guest speakers, field trips, service learning, issues surveys, and research or study projects on a local problem such as plant or animal inventories or pollution studies. Involvement of students in informal educational opportunities could also be relevant to this standard. If the community has significant cultural diversity, a study of science in different cultural contexts could be undertaken.

Culturally relevant teaching (Atwater, Crockett & Kilpatrick, 1996; Ladson-Billings, 1995) helps science come alive for many students, especially those who have traditionally been uninvolved in science. Examples and investigations based on students' personal experiences and on cultural contexts promote curiosity and help students build a personally meaningful framework for science (Atwater, 1994).

Values of the community, often religious values, may directly conflict with tenets of science. Teachers must study the composition of the community carefully and understand the beliefs that are commonly held by its members. Teachers of science should not feel forced to compromise the values and ethics of what they teach. Instead, they must find ways, through study and analysis, to accommodate these deeply held beliefs; for example, by discussing beliefs at a different level, i.e., by examining the role of belief in all human thought. By understanding that students are a product of the community, teachers may often find better ways to ensure that science is meaningful to them.

Applications in Programs

To meet this standard, candidates must know the community in which they teach. Programs should provide candidates with the background and tools they need to learn about the community. This could include a community survey or visits to a community website that provides demographic and resource information about the community. Candidates should also know how to obtain information from their students that might help them to understand their needs, and might lead to guest speakers from the students' families.

A good resource for finding out about the community is the local newspaper. News media may report on issues relevant to science and technology, which then may be used as the focus of discussion and cost-benefit analysis. It may be desirable for candidates to create and maintain a resource list for topics in their field and arrange to either take students to the field or have guest speakers come in. The Internet can also be a useful tool for finding resources in some communities.

It is not always necessary for candidates to arrange for guest speakers or a field trip in order to make use of community resources. Students, alone or in small study groups, may be asked to investigate questions, collect data, visit sites¸ attend presentations, or interview people after school or on weekends.

Standards 8: Assessment

Teachers of science construct and use effective assessment strategies to determine the backgrounds and achievements of learners and facilitate their intellectual, social, and personal development. They assess students fairly and equitably, and require that students engage in ongoing self-assessment. To show that they are prepared to use assessment effectively, teachers of science must demonstrate that they:

a. Use multiple assessment tools and strategies to achieve important goals for instruction that are aligned with methods of instruction and the needs of students.
b. Use the results of multiple assessments to guide and modify instruction, the classroom environment, or the assessment process.
c. Use the results of assessments as vehicles for students to analyze their own learning, engaging students in reflective self-analysis of their own work.

Discussion

The National Science Education Standards (NRC, 1995) give the topic of assessment considerable attention, an emphasis that highlights the importance of assessment to science teachers, who are called upon to evaluate diverse skills. Contemporary teachers must feel confident in using authentic assessment it to measure achievement of science standards and benchmarks (AAAS, 1997).

Assessment is not a punitive action; rather it should be a process of learning by teacher and student. Good assessment strategies help students learn about their strengths and weaknesses. Poor assessments result only in a sense of failure or incompetence for sincere students. Reflective teachers help their students identify and celebrate their achievements.

Central to the process of assessment is the concept of alignment: the consistency between goals, actions and assessments. New teachers must learn how to design instruction and assessments that are consistent with multiple goals, not just those aimed at content acquisition. In a climate of positive assessment, learners and their teachers look for evidence to document growth. Diagnostic, formative and summative assessment strategies are woven throughout instruction as a natural part of the classroom activities. Portfolios are often used to collect evidence of growth and change.

Multiple assessment methods including videotapes, demonstrations, practicum observations, discussions, reports, simulations, exhibitions and many other outcomes are useful alternatives to the traditional written test. Peer assessment in cooperative learning groups is especially useful for demonstrating skills using laboratory equipment, and for evaluating process skills such as the creation and interpretation of graphs. Computer-based testing can help students diagnose their own abilities while placing fewer demands on teacher time.

Authentic assessment has also become an important part of educational reform. It is "assessment that mirrors and measures students' performances in 'real-life' tasks and situations" (Hart, 1994, p, 106). It is expected that candidates should provide evidence of the ability to develop and use both authentic and traditional assessment strategies. This includes preparation on how to design and use valid and reliable rubrics.

Professional teachers accept responsibility for judging the relative success of activities they design (National Board for Professional Teaching Standards [NBPTS], 1996). They monitor the successes and failures of both individuals and classes. Such teachers use information about how students are doing "on average" to analyze the success of their instructional strategies. They know how to align instructional practices and materials with outcomes as measured on carefully selected assessment instruments (Webb, 1997).

Applications in Programs

An important tenet of education is that the mode of assessment often drives methods of instruction rather than the other way around. The very nature of a performance based teacher preparation program requires candidates to pay far more attention to determining the results of instruction than has been necessary in the past.

Multiple assessment tools should be aligned with the multiple purposes of instruction. Candidates should be called upon to justify their selection of assessment tools in relation to the purposes of the instruction. For example, it is clearly inconsistent to use a multiple-choice quiz to assess the result of an open inquiry. Variety of assessments does not just include different kinds of traditional and nontraditional assessments, but also assessments to measure different dimensions of learning—cognitive, affective and psychomotor knowledge and skills—and dispositions of students.

It would be expected that candidates should show at least some disposition to use assessments to guide and change instruction. These assessments may be formal or informal, formative or summative. A supervisor may note this occurring and assistant the candidate in reflecting upon this change. Alternatively, candidates may use pretests or may collect data formatively to determine whether further instruction on a concept or in a skill is needed. Some teachers have found it effective to asks students at the end of each class period to write something they have learned that day; they have then used the student response to guide their work the next day and clear up misconceptions or misunderstandings.

It is also important that teachers be able to involve students in self-analysis. Too often assessment is something done to students. It takes little effort for candidates to include items that require student reflection on tests, projects, or activities they have completed. Conferencing with students using data from their assessments may also be a way of involving students in self assessment as long as the students themselves are doing the assessing: such conferences would not meet standard 25 if it is just another form of teacher assessment.

Standard 9: Safety and Welfare

Teachers of science organize safe and effective learning environments that promote the success of students and the welfare of all living things. They require and promote knowledge and respect for safety, and oversee the welfare of all living things used in the classroom or found in the field. To show that they are prepared, teachers of science must demonstrate that they:

a. Understand the legal and ethical responsibilities of science teachers for the welfare of their students, the proper treatment of animals, and the maintenance and disposal of materials.

b. Know and practice safe and proper techniques for the preparation, storage, dispensing, supervision, and disposal of all materials used in science instruction.

c. Know and follow emergency procedures, maintain safety equipment, and ensure safety procedures appropriate for the activities and the abilities of students.

d. Treat all living organisms used in the classroom or found in the field in a safe, humane, and ethical manner and respect legal restrictions on their collection, keeping, and use.

Discussion

The National Standards for Science Education (NRC, 1996) identify the dimensions of the learning environment as providing (a) time for extended investigations; (b) a flexible and supportive setting for inquiry; (c) a safe working environment; (d) sufficient resources, including tools, materials, media and technological resources; (e) resources outside school; and (f) engagement of students. Some of these factors have been dealt with in other standards and will not be repeated here.

Safety and liability are especially of concern to science teachers, given the variety of environments in which they may teach and the materials they may use. Nagel (1982) recommended that safety education should be a condition of certification. Flinn Scientific Inc. (1992) has developed a generic chemical hygiene plan for high school laboratories covering many procedural issues. Guidelines and recommendations are also available from the American Chemical Society for chemistry laboratories (American Chemical Society, 1995). Yohe and Dunkleberger (1992) have suggested an inservice format for teaching safety that is applicable to all teachers of science.

In the same vein, teachers should also be aware of the legal issues related to liability for their actions. Purvis, Leonard and Boulter (1982) have delineated the conditions of negligence and liability and related them to school science in the important areas of lab security, appropriate facilities, proper instruction and protective gear. Because science teachers are particularly likely to encounter injuries among their students, they should thoroughly understand the criteria for liability and negligence, and defenses against negligence. By being aware of their responsibilities, they can act to ensure the well-being of the students under their care.

Weld (1990) discusses the need to provide an accessible and safe environment for all science students, including those with special needs. Teachers must demonstrate awareness of the impact of special needs on potentially difficult activities such as field trips. They should also be aware of steps they can potentially take to meet the needs of all learners, from customizing equipment to adapting lessons to using cooperative learning approaches.

Teachers should be aware of issues related to the keeping of animals in the classroom. The U.S. Humane Society recommends stringent controls on the keeping and handling of animals in the classroom (Carin, 1997). The National Association of Biology Teachers does not recommend such restrictions, but does recommend careful attention to the humane care and use of animals, awareness of dangers, and the use of alternatives to dissection when they are available (National Association of Biology Teachers, 1990). Plants may also be hazardous, both in and outside of the classroom (Riechard, 1993).

Applications in Programs

Teacher preparation programs must ensure that candidates possess the knowledge needed to maintain a safe environment for all students. This includes knowledge of how to avoid or control hazardous materials or organisms, how to prepare and/or store materials properly, and how to clean up spills and dispose of chemicals safely.

Candidates must know how to check and use safety equipment properly and the hazards of improperly shielded equipment, and must be able to avoid risks from fire hazards and biological contaminants.

It is also important that candidates actually behave in a safe manner, model ethical and safe behavior, and ensure that students behave safely at all times. They must give proper safety instruction and causations, and must label materials and equipment in such a way as to maintain safety.

In addition to safety concerns, candidates who may keep or use animals in the classroom or field should be knowledgeable of their care. They should know and comply with laws and professional standards for classroom treatment of animals and should be aware of regulations controlling the use of sentient, usually vertebrate, animals. They should be able to properly maintain the environment of the animals and dispose of wastes, respond to the illness of the animals and ensure that they have the food, water, space, shelter and care needed for their well-being.

Where candidates may use viruses, microorganisms, or other living things potentially harmful to students, candidates should know how to clean up the classroom and dispose of materials in order to maintain safety for students and anyone who may encounter such materials. Chemical hazards or biohazards must be dealt with according to rules and regulations that apply to all laboratories.

Candidates should know and respect restrictions on collecting and using plants and animals, or parts of plants and animals, from the wild. They should be aware of the potential hazards of common plants as well as animals.

Finally, they should know the common emergency precautions, responses, and reporting procedures that they are to follow in the event problems arise.

Both knowledge and behaviors are essential components in demonstrating that this standard is met. Safety readings, tests, artifacts, projects, classroom safety evaluations, and so forth may be used to demonstrate knowledge and attention to safety matters. Reviews of regulations related to the collection and use of living things and general guidelines for safety and use of living things may also contribute to evidence of preparation. Actual performance in the classroom might be demonstrated by completion of a safety and ethical behaviors rubric or checklist by cooperating teachers.

Standard 10: Professional Growth

Teachers of science strive continuously to grow and change, personally and professionally, to meet the diverse needs of their students, school, community, and profession. They have a desire and disposition for growth and betterment. To show their disposition for growth, teachers of science must demonstrate that they:

a. Engage actively and continuously in opportunities for professional learning and leadership that reach beyond minimum job requirements.

b. Reflect constantly upon their teaching and identify ways and means through which they may grow professionally.

c. Use information from students, supervisors, colleagues and others to improve their teaching and facilitate their professional growth.

d. Interact effectively with colleagues, parents, and students; mentor new colleagues; and foster positive relationships with the community.

Discussion

Teaching becomes a profession when teachers practice with a common knowledge base and apply their knowledge to effective practice (Wise & Leibbrand, 1993). Professional teachers must "be capable of profound reflection on practice, competent to enter into dialogue of the practice they know and the theory or literature they read; able to engage in . . . interpretation and critique with colleagues and with children; and able to observe, document, and analyze their own practice and experience, and take that analysis into the white-hot cauldron of public forums and public accountability" (Socketed, 1996, p.26).

To be truly professional, technical competencies must be linked to a set of professional virtues (Sergiovanni, 1992) among which is a commitment to growth and improvement characterized by efforts to move toward exemplary practice. Such commitment may be demonstrated through efforts to stay abreast of the latest research in practice, examination of one's own teaching, experimentation with new approaches, and the sharing insights with other teachers. This in turn requires numerous opportunities to develop the skills of reflection in the context of real life experiences. (Roychoudhury, Roth & Ebbing, 1993).

A commitment to excellence based on the needs of others as well as one's self is crucial. At the heart of this commitment is a willingness to trust others, behave ethically and collegially, and share with a community of learners. Mann (1995) found that teachers can be their own best resource for improvement when their ideas are trusted and supported.

Intrinsic, as opposed to extrinsic rewards are powerful motivators (Lortie, 1975) thus programs must takes steps to help candidates reflect upon their teaching and find ways they can grow professionally that will add value to their sense of self. Many studies affirm the central role of intrinsic motivation in facilitating professional development (Bookhart & Freeman, 1992; Espinet, Simmons & Atwater, 1992; Green & Weaver, 1992; Rogers, Bond, & Nottingham, 1997; Serow, 1994).

Applications in Programs

Programs must help candidates enter the professional community as science educators. Science teaching is a composite profession requiring knowledge and skills in both science and education. Ideally, these skills come together in the preparation program. Associations and activities related to science teaching are abundant. Participation in such activities at the local, state and national levels should be encouraged, some being required. They are a resource for improving one's teaching, but also they provide the opportunity for constructive interaction with others in the same field. Teacher preparation programs should keep records of such activity so that they may then try to increase the activity of their candidates year by year.

The best teachers tend to be goal-focused, but flexible and reflective. These characteristics allow them to relate to students and to modify and improve their practices. Candidates in teacher preparation programs must demonstrate the ability to reflect, but also to respond positively to constructive feedback from others. Few teacher educators are unfamiliar with candidates who enter their programs with preset ideas that they refuse to change, even when students do not respond well to them. It is imperative that such individuals not be allowed to continue on into teaching.

The ability to get along with others is crucial in education, certainly with students, but also with other stakeholders such as teachers, administrators, support staff and parents. Dispositional factors can be assessed through the behaviors of candidates; candidates should be held accountable for behaviors that are contrary to the expectations of the profession as determined by the faculty and reflected in these standards. Carefully constructed criteria are needed and may be used as a source of data for candidate preparation and practice by the program.

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Acknowledgements

NSTA Revision Task Force
Patricia Colbert-Cormier, Lafayette High School, Lafayette, LA
George Dewey, Chantilly High School, Chantilly, VA
Julie Gess-Newsome, Northern Arizona University, Flagstaff, AZ
Steven W. Gilbert, Virginia Polytech. Inst. and State Univ., Falls Church, VA, **Chair**
Vincent Lunetta, Pennsylvania State University, State College, PA
Cheryl L. Mason, San Diego State University, San Diego, CA
Maureen McMahon, California State University, Long Beach, Long Beach, CA
Jon Pedersen, The University of Oklahoma, Norman, OK
Dwight Sieggreen, Hillside Middle School, Northville, MI

NSTA Contributors
Craig Berg, University of Wisconsin Milwaukee; Jeanelle Bland, Eastern Connecticut State University; Alan Colburn, California State University Long Beach; Pamela Fraser-Abner, New York University; Nikki Hanegan, Southwest Consortium for the Improvement of Mathematics and Science Teaching; Charles Hutchinson, Georgia State University; Claudia Khourey-Bowers, Kent State University; Norman Lederman, Illinois Institute of Technology; David Rudge, Western Michigan University; Gary Varella, George Mason University; Julie Thomas, Texas Tech; Mark Windschitl, University of Washington.

National Association of Biology Teachers
Subject Content Advisory Group for Biology and Life Sciences

NABT Steering committee (NABT Board of Directors)
Brad Williamson, Olathe High School, Olathe, KS
Ann S. Lumsden, Florida State University, Tallahassee, FL
Catherine Wilcoxson-Ueckert, Northern Arizona University, Flagstaff, AZ
Toby M. Horn, District of Columbia Public Schools, Washington, DC
Wayne W. Carley, National Association of Biology Teachers, Reston, VA
Ann Haley MacKenzie, Miami University, Oxford, OH
Jane P. Ellis, Presbyterian College, Clinton, SC
Rebecca E. Ross, Cave Spring High School, Roanoke, VA
Cissy Bennett, Alabama School of Fine Arts, Birmingham, AL

NABT Working committee
Catherine Wilcoxson Ueckert, Northern Arizona University, Flagstaff, AZ
Jane P. Ellis, Presbyterian College, Clinton, South Carolina.
Wayne Carley, National Association of Biology Teachers, Reston, VA

The policy committees are responsible for writing a significant portion of this document:

NABT Policy committees
***Statement on Teaching of Evolution/Scientific Integrity*:**
Dick Storey, The Colorado College, Colorado Springs, Colorado; Bill McComas, University of Southern California; Brian Alters, McGill University, Montreal Quebec; Michael Clough, Iowa State University, Ames, Iowa; Joe McInerney, National Coalition for Health, Professional Education and Genetics; Betsy Ott, Biology Instructor, Tyler Junior College; and Dan Wivagg, Baylor University, Waco, Texas

***Role of Laboratory and Field Instruction in Biology Education*:**
Bill Leonard, Clemson University, Clemson, South Carolina; Claudia Fowler, Louisiana State University, Baton Rouge, LA; Nancy Ridenour, Ithaca High School, Ithaca, NY; Carol Stone Alameda, California

***Biology Teaching Standards*:**
Ted Tsumura, George Washington High School, Denver, Colorado; Marjorie King, Jefferson Parish Schools, Louisiana

The Use of Animals in Biology Education
Gordon Uno, University of Oklahoma, Norman, Oklahoma; Wayne Carley, National Association of Biology Teachers, Reston, VA

NABT Reviewers:
Dolores Biggerstaff, Flagstaff High School, Flagstaff, AZ; Rodger Bybee, BSCS, Colorado Springs, Colorado; Pam Dryer, Flagstaff High School, Flagstaff, AZ; Dr. Anita Dutrow, Presbyterian College, Clinton, South Carolina; Michael DuBosh, Flagstaff High School, Flagstaff, AZ; Dr. Hans Gunderson, Northern Arizona University, Flagstaff, AZ
Carl Koch, retired high school teacher, Aurora, Illinois; Kim Leeman, middle level science teacher, Nashua, New Hampshire; Deborah Romanek, Nebraska Department of Education, Omaha, NE; Gordon Uno, University of Oklahoma, Norman, Oklahoma; Julie Vlieg, Sinagua High School, Flagstaff, AZ; Darcie Whitney, Mount Elden Middle School, Flagstaff, AZ

American Chemical Society
Science Content Advisory Group for Chemistry

Pam Abbott, Roxana High School, Roxana, IL
Connie Blasie, University of Pennsylvania, Philadelphia, PA
Joe Heppert, University of Kansas, Lawrence, KS 66045
Margaret Merritt, Wellesley College Wellesley, MA

George Palladino, University of Pennsylvania, Philadelphia, PA
Kathryn Scantlebury, University of Delaware, Newark, DE
Barb Sitzman, Chatsworth High School, Chatsworth, CA
Michael Tinnesand, American Chemical Society. Washington DC
Pernell Williams, Friendship Edison Collegiate Academy, Washington, DC

National Earth Science Teachers Association
Science Content Advisory Group for Earth/Space Sciences

Working Committee
Howard Dimmick, Stoneham High School, Stoneham, MA
Carl F. Katsu, Fairfield High School, Fairfield, PA
Sharon Stroud, Widefield High School, Colorado Springs, CO

Contributors
John Benhart, Shippensburg University, Shippensburg, PA
Susan Buhr, University of Colorado, Boulder, CO
Barbara Cheyney, The Haverford School, Haverford, PA
Charles Engle, Fairfield Middle School, Fairfield, PA
Michelle Hall-Wallace, University of Arizona, Tucson, AZ

American Association of Physics Teachers
Science Content Advisory Group for Physics

Writers/Contributors
James H. Nelson, University HS, Orlando,
Steven Shropshire, Idaho State University, Pocatello, ID
William McNairy, Duke University, Durham, NC
Stamatis Vokos, Seattle Pacific University, Seattle, WA
Len Jossem, Ohio State University, Columbus, OH
Steven Turley, Brigham Young University, Provo, UT
Gene Ewald, Cuyahoga Falls, OH

1998 NSTA Standards for Science Teacher Preparation
1998 Original Task Force and Reviewers

Task Force Members
Steven W. Gilbert, Indiana University Southeast (Chair); Hans Andersen, Indiana University; Bill Baird, Auburn University; James Ellis, The University of Kansas; Robert Fisher, Illinois State University; Julie Gess-Newsome, The University of Utah; Paul Kuerbis, The Colorado

College; Norman Lederman, Oregon State University; Cheryl Mason, San Diego State University; Wendell Mohling, National Science Teachers Association; Walter Smith, The University of Akron; Barbara Spector, The University of South Florida

Contributors

Dale Banks, St. Mary's College (IN); Michael Clough, University of Iowa; Barbara Crawford, Oregon State University; Rodney L. Doran, SUNY at Buffalo; Sandy Enger, The University of Alabama at Huntsville; Robert Fisher, Illinois State University; Robin Freedman, Buffalo State College (NY); Jennifer Helms, The University of Colorado; Tom Keating, Indiana University; Carolyn Keys, Georgia State University; Karen Lind, The University of Louisville; William McComas, The University of Southern California; Don Orlich, Washington State University; Jon Pedersen, Eastern Carolina University; Patricia R. Simpson, St. Cloud State University; Dana Zeidler, The University of South Florida