

NSTA Standards for Science Teacher Preparation

Standard 1: Content Knowledge

Content knowledge is frequently shown in the research to be one primary characteristic of the competent teacher who also needs to know how to teach the material they know (Darling-Hammond, 2006; Grossman, Schoenfield & Lee, 2005; Kellough, 2003; Diaz, et.al., 2006). Since the nineteenth century, teachers were subjected to tests of content that the teacher was to teach (Ravitch, 2002). Due to the historical important of science content as well as the research that shows its importance, the standards for programs that prepare science teachers assures that content knowledge is delivered and assessed as part of the program. Content knowledge is represented in content checklists for program designs (Appendix 1) as well as scores on licensure tests. These evidences should allow the program preparing science teachers to assess the breadth and depth of content coverage.

NSTA Standard 1: Content Knowledge

Effective teachers of science understand and articulate the knowledge and practices of contemporary science. They interrelate and interpret important concepts, ideas, and applications in their fields of licensure.

Below are the elements of the standard.

Preservice teachers will:

1a) Understand the major concepts, principles, theories, laws, and interrelationships of their fields of licensure and supporting fields as recommended by the National Science Teachers Association.

1b) Understand the central concepts of the supporting disciplines as outlined in the content analysis form. (See below for the content analysis)

1c) Show an understanding of state and national curriculum standards and their impact on the content knowledge necessary for teaching P-12 students.

Assessment: *These elements are usually met using Assessment 1 and 2.*

Science Content Requirements for the NSTA 2011 Standards

A. Secondary Science Teachers

A.1. All Secondary Science Teachers

Secondary teachers are generally prepared with depth and breadth in the content of a given field. 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 and supporting competencies from related disciplines.

A.2. Teachers of Biology

A.2.a. *Core Competencies.* All teachers of biology should 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. Ecological systems including the interrelationships and dependencies of organisms with each other and their environments.
4. Population dynamics and the impact of population on its environment.
5. General concepts of genetics and heredity.
6. Organizations and functions of cells and multi-cellular systems.
7. Behavior of organisms and their relationships to social systems.
8. Regulation of biological systems including homeostatic mechanisms.
9. Fundamental processes of modeling and investigating in the biological sciences.
10. Applications of biology in environmental quality and in personal and community health.
11. Bioenergetics including major biochemical pathways
12. Molecular genetics and heredity and mechanisms of genetic modification
13. Molecular basis for evolutionary theory and classification

A.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:

14. Biochemical interactions of organisms and their environments.
15. Causes, characteristics and avoidance of viral, bacterial, and parasitic diseases
16. Molecular genetics
17. Issues related to living systems such as genetic modification, uses of biotechnology, cloning, and pollution from farming.
18. Historical development and perspectives in biology including contributions of significant figures and underrepresented groups, and the evolution of theories in biology.
19. How to design, conduct, and report research in biology.

A.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:

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

A.3. Teachers of Chemistry

A.3.a. *Core Competencies.* All teachers of chemistry should be prepared lead students to understand:

1. Fundamental structures of atoms and molecules.
2. Basic principles of ionic, covalent, and metallic bonding.
3. Periodicity of physical and chemical properties of elements
4. Laws of conservation of matter and energy
5. Fundamentals of chemical kinetics, equilibrium, and thermodynamics.
6. Kinetic molecular theory and gas laws
7. Mole concept, stoichiometry, and laws of composition.

8. Solutions, colloids, and colligative properties.
9. Acids/base chemistry
10. Fundamental oxidation-reduction chemistry, fundamental organic chemistry and biochemistry
11. Fundamental biochemistry
12. Nature of Science and the fundamental processes in chemistry.
13. Applications of chemistry in personal and community health and environmental quality
14. Fundamentals of nuclear chemistry
15. Historical development and perspectives in chemistry

A.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:

16. Principles of electrochemistry
17. Transition elements and coordination compounds
18. Molecular orbital theory, aromaticity, metallic and ionic structures, and correlation to properties of matter.
19. Advanced concepts in chemical kinetics, equilibrium, gas laws, and thermodynamics.
20. Lewis structures and molecular geometry.
21. Advanced concepts in acid/base chemistry, including buffers
22. Major biological compounds and reactions
23. Solvent system concepts
24. Chemical reactivity and molecular structure including electronic and steric effects
25. Organic chemistry
26. Historical development and perspective in chemistry including synthesis, reaction, mechanisms, and aromaticity
27. Green chemistry and sustainability
28. How to design, conduct, and report research in chemistry.

A.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:

29. Biology, including molecular biology, and ecology.
30. Earth science, including geochemistry, cycles of matter, and energetics of Earth systems.
31. Physics, including energy, electricity, and magnetism. Also including properties and function of waves, of motion, and of forces.
32. Mathematical and statistical concepts including the use of statistics, of differential equations and of calculus.

A.4. Teachers of the Earth and Space Sciences

A.4.a. *Core Competencies.* All teachers of the Earth and space sciences should be prepared 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.

A.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 including contributions of significant figures and underrepresented groups, and the evolution of theories in the fields of Earth and Space Sciences.
21. How to design, conduct, and report research in the Earth and space sciences.

A.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:

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

A.5. *Teachers of Physics*

A.5.a. *Core Competencies.* All teachers of physics should be prepared lead students to understand:

1. Energy, work, and power.
2. Motion, major forces, and momentum.
3. Newtonian physics 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.

A.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 energy-matter relationships.
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.

A.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 and space sciences 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.

Specific Licensure 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. In this case, the preservice teacher should have eighty percent of the core competencies in the primary discipline, eighty percent of the advanced competencies in the primary discipline and eighty percent of the supporting competencies in the remaining sciences.
2. Dual field programs, which require equal preparation in two disciplines. In this case, preservice teachers should have eighty percent of the advanced competencies in both disciplines, eighty percent of the core competencies in both disciplines, and eighty percent of the supporting competencies in both disciplines.
3. Broad field programs, which require preparation in three or four disciplines. In this case, preservice teachers should have eighty percent of the advanced competencies in one discipline, eighty percent of the core competencies in the applicable disciplines and eighty percent of the supporting competencies in the applicable disciplines.
4. General Science Teachers, which require general science knowledge. In this case, preservice teachers should have eighty percent of the core competencies in each of the four disciplines.

B. Elementary Science Specialists and Middle Level Teachers of Science

B.1. Elementary science specialists and middle level teachers of science should be prepared with a strong emphasis on collaborative inquiry in the laboratory and field. 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. They should be prepared to lead students to understand in each content area of biology, physical sciences and earth and space science. The sciences should be interwoven to develop interdisciplinary perspectives. To achieve this, teachers of science at this level should have eighty percent of the competencies described for the elementary generalist for each area: B.2, B.3, B.4, and B.5.

B.2. In relation to biology, elementary science specialists and middle level teachers of science should be prepared in biology to lead students to understand:

1. Features distinguishing living from nonliving systems.
2. Characteristics distinguishing plants, animals, and other living things.
3. Multiple ways to order and classify living things.
4. Ways organisms function and depend on their environments
5. Ways organisms are interdependent.
6. Reproductive patterns and life cycles of common organisms.
7. Growth, change, and interactions of populations to form communities.
8. Factors governing the structures, functions, and behaviors of living systems.
9. Multiple systems of classification of organisms.
10. Cycles of matter, and flow of energy, through living and nonliving pathways.
11. Natural selection, adaptation, diversity, and speciation.
12. Structure, function, and reproduction of cells, including microorganisms.
13. Levels of organization from cells to biomes.
14. Reproduction and heredity, including human reproduction and contraception.
15. Behavior of living systems and the role of feedback in their regulation.
16. Hazards related to living things including allergies, poisons, disease, and aggression.

B.3. In relation to physical sciences, elementary science specialists and middle level teachers of science should be prepared in chemistry and physics to lead students to understand:

1. Properties of matter such as mass, solubility, and density.
2. Combinations of matter to form solutions, mixtures, and compounds with different properties.
3. Variations in the physical and chemical states of matter and changes among states.
4. Ordering and classification of matter and energy and their behaviors.
5. Factors affecting the position, motion and behavior of objects.
6. Properties of simple machines and tools, such as levers and screws.
7. Properties of light, electricity, sound, and magnetism.
8. Types of energy, energy sources, and simple transformations of energy.
9. Properties and applications of sound, light, magnetism, and electricity.
10. Potential and kinetic energies and concepts of work.
11. Energy flow in physical and chemical systems, including simple machines
12. States of matter and bonding in relation to molecular behavior and energy.
13. Conservation of matter and energy.
14. Classifications of elements and compounds.
15. Solvents (especially water) and solutions.
16. Chemical nature of the earth and its living organisms.
17. Chemical, electrical and radiation hazards.

B.4. In relation to Earth and space sciences, elementary science specialists and middle level teachers of science should be prepared in Earth and space sciences to lead students to understand:

1. Natural objects in the sky and why they change in position and appearance.
2. Causes of the seasons and seasonal changes.
3. Changes in the atmosphere resulting in weather and climate.
4. Changes in the Earth creating and eroding landforms.
5. Basic properties of rocks, minerals, water, air, and energy.
6. Differences between renewable and nonrenewable natural resources.
7. Structures of objects and systems in space.
8. Earth's structure, evolution, history, and place in the solar system.
9. Characteristics and importance of oceans, lakes, rivers, and the water cycle.
10. Characteristics of the atmosphere including weather and climate.
11. Changes in the Earth caused by chemical, physical, and biological forces.
12. Causes and occurrences of hazards such as tornados, hurricanes, and earthquakes.

13. Characteristics and importance of cycles of matter such as oxygen, carbon, and nitrogen.
14. Characteristics of renewable and nonrenewable natural resources and implications for their use.
15. Interactions among populations, resources, and environments.

B.5. To create interdisciplinary perspectives and to help students understand why science is important to them, elementary science specialists and middle level teachers of science should be prepared to lead students to understand:

1. Differences between science, as investigation, and technology as design.
2. Impact of science and technology on themselves and their community, and on personal and community health.
3. How to use observation, experimentation, data collection, and inference to test ideas and construct concepts scientifically.
4. How to use metric measurement and mathematics for estimating and calculating, collecting and transforming data, modeling, and presenting results.
5. Interrelationships of pure and applied sciences, and technology.
6. Applications of science to local and regional problems and the relationship of science to one's personal health, well-being, and safety.
7. Historical development and perspectives on science including contributions of underrepresented groups and the evolution of major ideas and theories.
8. Applications of science to the investigation of individual and community problems.
9. Use of technological tools in science, including calculators and computers.
10. Applications of basic statistics and statistical interpretation to the analysis of data.

Standard 2: Content Pedagogy

Students come to school already holding conceptions about how things work. Many times these conceptions are inaccurate, and have developed from not understanding physical phenomena students have observed in nature (Tsai & Chang, 2005). Many times these naïve conceptions persist into adolescence and adulthood. Teachers need to be able to assess students' prior science knowledge and design instruction that helps students alter their naïve conceptions (Babai, Sekal, & Stavy, 2010). Reflecting and representing what a student has learned is an assessment method that has been determined to help students problem solve (Toth, Suthers, & Lesgold, 2002). The NSTA Standards for Science teacher Preparation recognize these needs and will assess them, ordinarily, by planning a unit of instruction that evidences their abilities in each area of the standard.

NSTA Standard 2: Content Pedagogy
Effective teachers of science understand how students learn and develop scientific knowledge. Preservice teachers use scientific inquiry to develop this knowledge.
Below are the elements of the standard.
Preservice teachers will: 2a) Plan multiple lessons using a variety of inquiry approaches that demonstrate their knowledge and understanding of how students learn science. 2b) Include active inquiry lessons where students collect and interpret data in order to develop and communicate concepts and understand scientific processes, relationships and natural patterns from empirical experiences. 2c) Design instruction and assessment strategies that confront and address naïve concepts/preconceptions.
Assessment: <i>These elements are usually met using Assessment 3 – Unit Plan</i>

Standard 3: Learning Environments

Early on, what worked in educational instruction was largely related to what students learned and how successful they were in mastering the concepts presented. The essential elements of instruction, the in-service program resulting from the theories resulting from Hunters (1982) work, focus on what many term as a “seven step” model that describes one type of teaching that quickly turned into a checklist used for teacher evaluation. A paradigm shift was realized and clearly articulated by Bransford, Brown and Cocking (2000) when they stated “educational goals for the twenty-first century are very different from the goals of earlier times” (p.131). Many reform initiatives (Project 2061, 1990; National Research Council, 1996; National Commission on Mathematics and Science Teaching for the 21st Century, 2000) pointed to a need for reform in science education, a shift in emphasis was urged to a more student “inquiry” format. The development of an appropriate environment for science teaching is assessed in Standard 3 using, typically, a student-developed unit plan.

NSTA Standard 3: Learning Environments

Effective teachers of science are able to plan for engaging students in science learning by setting appropriate goals that are consistent with knowledge of how students learn science and are aligned with state and national standards. The plans reflect the nature and social context of science, inquiry, and appropriate safety considerations. Candidates design and select learning activities, instructional settings, and resources--including technology, to achieve those goals; and they plan fair and equitable assessment strategies to evaluate if the learning goals are met.

Below are the elements of the standard.

Preservice teachers will:

3a) Use a variety of strategies that demonstrate the candidates’ knowledge and understanding of how to select the appropriate teaching and learning activities – including laboratory or field settings - to help all students learn.

3b) Plans include active inquiry lessons where students collect and interpret data in order to develop concepts, understand scientific processes, relationships and natural patterns from empirical experiences.

3c) Plan fair and equitable assessment strategies to analyze student learning and to evaluate if the learning goals are met. Assessment strategies are designed to continuously evaluate preconceptions and ideas that students hold and the understandings that students have formulated.

3d) Plan a learning environment and learning experiences for all students that demonstrate chemical safety, safety procedures, and the ethical treatment of living organisms within their licensure area.

Assessment: *Standard 3 is usually met using Assessment 3 - Unit Plan*

Standard 4: Safety

It is incumbent on programs that prepare science teachers to recognize that all teachers (including new teachers on their first day of teaching) have a legal responsibility to provide a “duty of care” for students. The duty of care responsibilities relative to students and other school employees are described in three categories: Duty of Instruction, Duty of Supervision and Duty to Maintain Equipment and facilities (Science & Safety: Making the Connection, 2000). Roy (2004, p.10) cautions that “Teachers are expected to be knowledgeable about proper care of organisms under study and the safety of their students.” Yet according to Kaufman (2011), at least 21 students have been injured in high school laboratories from 2000-2010. Programs that prepare future science teachers must document their students’ preparation in the area of science safety, typically, through a student teaching evaluation form that specifically documents these abilities.

NSTA Standard 4: Safety

Effective teachers of science can, in a P-12 classroom setting, demonstrate and maintain chemical safety, safety procedures, and the ethical treatment of living organisms needed in the P-12 science classroom appropriate to their area of licensure.

Below are the elements of the standard.

Preservice teachers will:

4a) Design activities in a P-12 classroom that demonstrate the safe and proper techniques for the preparation, storage, dispensing, supervision, and disposal of all materials used within their subject area science instruction.

4b) Design and demonstrate activities in a P-12 classroom that demonstrate an ability to implement emergency procedures and the maintenance of safety equipment, policies and procedures that comply with established state and/or national guidelines. Candidates ensure safe science activities appropriate for the abilities of all students.

4c) Design and demonstrate activities in a P-12 classroom that demonstrate ethical decision-making with respect to the treatment of all living organisms in and out of the classroom. They emphasize safe, humane, and ethical treatment of animals and comply with the legal restrictions on the collection, keeping, and use of living organisms.

Assessment: Elements 4a, 4b and, 4c are usually met using Assessments 3- Unit Plan, 4- Student Teaching Observation Form.

Standard 5: Impact on Student Learning

The ability to create both authentic formative and summative assessment experiences based on standards is necessary if the teacher wants to generate and use data. The data is used to gauge student understanding that will, in turn, guide a teachers instructional decisions. (Darling-Hammond, 2006). The ability to use assessments for professional and pedagogical purposes is recognized as a critical element of teaching. Bloch, & Laurie (2009) state, “Central to planning effective science units and lessons is identifying from the beginning how students will be assessed” (218). . The teacher in return would need to use data from formative assessment to reflect on whether students did, in fact, learn science (National Research Council [NRC], 1996). Providing both evidence of student learning and reflection on the results is most frequently provided by a paper that provides data, interpretation and impact of the data on student learning.

NSTA Standard 5: Impact on Student Learning

Effective teachers of science provide evidence to show that P-12 students’ understanding of major science concepts, principles, theories, and laws have changed as a result of instruction by the candidate and that student knowledge is at a level of understanding beyond memorization.

Below are the elements of the standard.

Preservice teachers will:

5a) Preservice teachers will collect, organize, analyze, and reflect on diagnostic, formative and summative evidence of a change in mental functioning demonstrating that scientific knowledge is gained and/or corrected.

5b) Provide data to show that P-12 students are able 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.

5c) Engage students in developmentally appropriate inquiries that require them to develop concepts and relationships from their observations, data, and inferences in a scientific manner.

Assessment: *These elements are usually met using Assessment 5 – Evidence of P-12 student learning*

Standard 6: Professional Knowledge and Skills

The Standards for Science Teacher Preparation recognize that a broad and deep understanding of content must be accompanied by explorations of how the content can be put into practice as the educator adopts their role. The content is important and must be accurate, but without an ability to communicate within their role using the content, the professional educator would be ineffective. Good professional development must include both content and pedagogical content knowledge (Grossman, Schoenfeld & Lee, 2005; Bybee, 2010). Good professional development will allow teacher candidates to demonstrate that they can keep their content and pedagogical content knowledge accurate and effective (Stiles & Mundry, 2002; National Science Education Standards, 1996). Developing the processes and skills of reflection will enable the candidate to improve their practice based on experience (Darling-Hammond, 2006). Issues of professional development and reflection are important as habits to begin during a preservice teacher preparation program and are frequently documented through the use of an assignment that documents both aspects.

Standard 6: Professional Knowledge and Skills
Effective teachers of science strive continuously to improve their knowledge and understanding of the ever changing knowledge base of both content and science pedagogy. They identify with and conduct themselves as part of the science education community.
Below are the elements of the standard.
Preservice teachers will: 6a) Engage in professional development opportunities in their content field such as talks, symposiums, research opportunities, or projects within their community. 6b) Engage in professional development opportunities such as conferences, research opportunities, or projects within their community.
Assessment: <i>These elements are usually met using Assessment 6 – Evidence of Professional Knowledge and Skills</i>