KANSAS

Science Education Standards

Adopted February 2007
Revised August 2007

Leadership and support for student learning.

Kansas State Department of Education

Table of Contents

Dedication

The writing committee dedicates the *Kansas Science Education Standards* to all Kansans. With this document, we pass on the legacy of our own teachers, who helped us understand that lifelong learners of science live more productive, responsible, and fulfilling lives. We share this legacy with our students, active participants in the future of Kansas.

Standards Development Committee

Stephen Angel, Topeka, Chemistry Professor, Washburn University
Rick Badley, Olathe, Chemistry Professor, Mid-America Nazarene University
Jim Benz, Shawnee, Science Teacher, Turner Middle School
Ken Bingman, Spring Hill, Biology Teacher, Blue Valley West High School
Nancy Bohler, Wellington, Chemistry and Physical Science Teacher, Campus High School
Linda Carlton, Wichita, Elementary Science Coordinator (retired)
*Steven Case, Overland Park, Research Assistant Professor, University of Kansas
Nikki Cooper, Bonner Springs, 3rd and 4th Grade Teacher, Edwardsville Elementary
Janice Crowley, Wichita, Chemistry Teacher, Collegiate School
Larry Downing, Pittsburg, Science Teacher, Pittsburg Middle School
Angela Epps, Shawnee, Geosciences and Astronomy Teacher, Olathe North High School
Dave Kraemer, Salina, Physics Professor. Kansas Wesleyan University
Jack Krebs, Lawrence, Mathematics Teacher and Technology Coordinator, Oskaloosa High School
Jay Nicholson, Valley Center, Science Teacher, Trinity Academy
Twyla Sherman, Wichita, Elementary Science Education Professor, Wichita State University,
John Staver, Manhattan, Science Education Professor, Kansas State University
Sandy Tauer, Derby, Science and Mathematics Coordinator (retired)
**Carol Williamson, Olathe, PreK-12 Science Coordinator, Olathe District Schools
John Yost, Moundridge, Hesston College Agronomy Professor

****Committee Chair***
****Committee Co-chair**

Mission Statement

Kansas science education contributes to the preparation of all students as lifelong learners who can use science to make reasoned decisions that contribute to their local, state, national and international communities.

Vision Statement

Science education in Kansas is intended to help students to develop the understandings and intellectual abilities they need to lead personal fulfilling lives and to equip them to participate thoughtfully with fellow citizens in building and protecting an open, equitable, and vital society. The educational system must prepare the citizens of Kansas to meet the challenges of the 21st century and to be competitive in a world that has an increasingly level playing field. With this in mind, the intent for the *Kansas Science Education Standards* can be expressed in a single phrase that embodies both excellence and equity: High quality science standards for all students. These standards apply to all students, regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and/or motivation in the sciences.

Science education in Kansas strongly emphasizes the skill of scientific inquiry as an essential component of scientific literacy. These standards are written to make, "Science as inquiry ... basic to science education and a controlling principle in the ultimate organization and selection of students' activities" (NRC, 1996). The National Science Education Standard on Inquiry clearly state actions students participate in as a part of an inquiry-based science education:

> "Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments." (NRC, 1996, p. 105)

These standards are built on the premise that science is an active process; something that students and adults actively do, not something that is only demonstrated for them. This active engagement allows teachers to operate as a mediator, guide, provocateur, friend and co-learner with their students. Knowledge gained in the context of scientific inquiry provides fertile ground where students can transfer their knowledge to multiple contexts. As a result of the experiences outlined in these standards students have a deep understanding of science knowledge and are empowered to add to the growing body of scientific knowledge.

Purpose of this Document

These standards, benchmarks, indicators, and examples are designed to assist Kansas educators in selecting and developing local curricula, carrying out instruction, and assessing students' progress. They will also serve as the foundation for the development of state assessments in science. Finally, these standards, benchmarks, indicators, and examples represent high, yet reasonable expectations for all students.

The *Kansas Science Education Standards*:

- Provide criteria Kansas educators and stakeholders can use to judge whether particular actions will serve the vision of a scientifically literate society.

- Bring coordination, consistency, and coherence to the improvement of science education.

- Advocate that science education must be developmentally appropriate and reflect a systemic, progressive approach throughout the elementary, middle, and high school years. (See Implementation, p. ix)

These standards should not be viewed as a state curriculum or instructional strategy. The content embodied in these standards can be organized and presented with many different emphases and perspectives in local district curricula. (See Implementation, p. ix)

Development of the Kansas Science Education Standards

The original *Kansas Curricular Standards for Science* was drafted in 1992, approved by the Kansas State Board of Education in 1993, and up-dated in 1995. Although all of this work occurred prior to the release of the *National Science Education Standards* in 1996, the original Kansas standards reflect early work on the national standards.

At the August, 1997 meeting of the Kansas State Board of Education, the Board directed that academic standards committees composed of stakeholders from throughout Kansas should be convened in each curriculum area defined by Kansas law (reading, writing, mathematics, science, and social studies). The 1998-2001 science standards committee was able to build upon and benefited from a great deal of prior work done on a national level; the *National Science Education Standards* published by the National Research Council; *Benchmarks for Science Literacy* from Project 2061 of the American Association for the Advancement of Science (AAAS); and *Pathways to the Science Standards*, published by the National Science Teachers Association (NSTA). This allowed the foundation for the *Kansas Science Education Standards (2001)* to be based on research and on the work of over 18,000 scientists, science educators, teachers, school administrators and parents across the country that produced national standards as well as the school district teams and thousands of individuals who contributed to the benchmarks. *Kansas Curricular Standards for Science* was approved by the Kansas State Board of Education on February 14, 2001.

As part of the federal reauthorized 2002 Elementary and Secondary Education Act (ESEA), known as “No Child Left Behind’ and as part of the state’s requirement to review curriculum standard every three years, at the April, 2004 meeting of the Kansas State Board of Education, the Board directed that academic standards committees should be convened and charge to:

- Review the current science standards as well as national and other state standards in light of what students should know and be able to do by each grade level assessed.
- Review the format of the curricular standards to ensure they are understandable and useable.
- Determine the level of specificity needed at each level – standards, benchmark or indicator – in terms of the content to be learned and complexity of skill assessed on the state assessments.
- Ensure standards are written in specific and measurable terms to provide greater instructional clarity for at least each grade level assessed.
- Recommend essential indicators to be assessed in the state assessment program, including additional indicators local districts may use to enrich and enhance their curriculum.
- Review the modified and extended standards to include in the revised standards document.
- Submit first draft of the revised science standard to the State Board by December, 2004.

These standards are based on the *National Science Education Standards* (NRC, 1996). The process of developing these standards has been advised by Kansas Educators (November 2004 Field Review), Kansas Citizens (February 2005 Public Hearings), and the external review of the standards conducted by McREL (Mid-continent Research and Education Leadership). In developing the 2006 Kansas Science Education Standards, portions of documents developed by the National Research Council, AAAS, and NSTA have been used with permission.

Organization of the Kansas Science Education Standards

Each standard in the main body of the document contains a series of benchmarks, which describe what students should know and be able to do at the end of a certain point in their education (i.e., grades 2, 4, 7, and 12). Each benchmark contains a series of indicators, which identify what it means for students to meet a benchmark. Indicators are frequently followed by examples, which are specific, concrete ideas or illustrations of the standards writers' intent.

Standards

There are seven standards for science. These standards are general statements of what students should know, understand, and be able to do in the natural sciences over the course of their K-12 education. The seven standards are interwoven ideas, not separate entities; thus, they should be taught as interwoven ideas, not as separate entities. These standards are clustered for grade levels K-2, 3-4, 5-7, and 8-12.

1. Science as Inquiry
2. Physical Science (Physics and Chemistry)
3. Life Science
4. Earth and Space Science
5. Science and Technology
6. Science in Personal and Environmental Perspectives
7. History and Nature of Science

Benchmarks

Benchmarks are specific statements of what students should know and be able to do at a specified point in their schooling. Benchmarks are used to measure students' progress toward meeting a standard. In these standards, benchmarks are defined for grades 2, 4, 7, and 12.

Indicators

Indicators are statements of the knowledge or skills which students demonstrate in order to meet a benchmark. Indicators are critical to understanding the standards and benchmarks and are to be met by all students. The indicators listed under each benchmark are not listed in priority order, nor do the indicators include all potential topics related to the benchmarks. Moreover, the list of examples with each indicator should be considered as representative but not as comprehensive or all-inclusive.

Instructional Examples, Teacher Notes, and Additional Specificity

To assist in the implementation of the standards, additional information is added to indicators in the form of Instructional Examples, Teacher Notes, and Additional Specificity. Instructional Examples offer~~s~~ an activity or a specific concrete instance of an idea of what is called for by an indicator. Teacher Notes clarify vocabulary. Information labeled Additional Specificity provides an illustration of the meaning or intent of an indicator. Like the indicators themselves, these forms of information are considered to be representative but not comprehensive or all-inclusive.

Linking the Standards to the Kansas Science Assessment

Assessed indicators are marked with a delta. The delta with a numbered indicator means that this indicator has been designated for emphasis on the new Kansas Science Assessments.

- An indicator with a delta ▲ in the Grades K-4 Standards will be assessed at Grade 4.
- An indicator with a delta ▲in the Grades 5-7 Standards will be assessed at Grade 7.
- An indicator with a delta ▲ in the Grades 8-12 Standards will be assessed at a high school grade by the Kansas State Assessment. The marked indicators are aligned with the ACT science subtest and may be helpful for students who choose to take this assessment.

Implementation of the Kansas Science Education Standards:

Actions by Kansas school districts to implement the Kansas Science Education Standards (KSES) should include:

1. Use the Kansas Science Education Standards as a framework for local curriculum, including Extended Standards for special needs students. KSES provides a framework for building local curriculum. Local curriculum, developed from these standards, determines what is taught/learned in science. Local curriculum also provides local district with a guide for selecting instructional resources.

2. Distribute complete sets of Kansas Science Education Standards to all K-12 science teachers and K-12 administrators. Make all grade levels aware of the assessed indicators, and include all the KSES standards in local district K-12 science curriculum. Local districts are advised to insure that all of the KSES are included in local curriculum and that assessed indicators are not the entire focus of the use of the standards document.

3. Match each KSES indicator with the local grade level that includes the indicator in local curriculum. Determine what local district action is needed if there are KSES standards/indicators that are not addressed in local curriculum. (Note: Once approved by the KSBE, these standards will include in the Appendix a version of the standards that show a sample grade-by grade breakdown of the grade span indicators.)

4. Develop local curriculum that integrates science learning with concepts and skills of other curriculum areas, especially math.

5. Classroom teachers select developmentally appropriate instructional strategies to develop the understandings and abilities described in KSES. The importance of inquiry does not imply that all teachers should pursue a single approach to teaching science.

6. Develop local assessments that support the Kansas Science Education Standards and extend beyond learning the measured Kansas Science Assessments.

7. Provide ongoing, research-based professional development for K-12 science teachers (all grade levels, not just assessed grade levels) to assure that all students have a highly qualified science teacher. Science teachers need professional development time and support for a creative teaching and learning environment described by KSES as lab-based, inquiry science.

8. Provide the resources needed for science learning: highly qualified science teachers, adequate class time, a rich array of learning materials, equipped and safe science classrooms, and the resources of the communities surrounding the schools.

9. Focus on K-12 student learning in science, while meeting the science learning requirements of federal “No Child Left Behind” legislation (NCLB) and Quality Performance Accreditation (QPA). Inform all science teachers of Kansas State Department of Education (KSDE) assessment schedules and procedures. No Child Left Behind (2002 federal legislation) requires states to assess annually in science, beginning in 2007, at designated grade levels. (See “Linking the Standards to the Kansas Science Assessment,” p. 4) NCLB also requires school districts to provide highly qualified science teachers for all students by 2005.

Quality Performance Accreditation is the process for accrediting Kansas schools. Each school should include science student achievement targets in the School Improvement Plan.

10. These standards provide a framework for local curriculum for science knowledge and skills for all students to attain. For students going beyond the expectations for all students with their high school science education, taking advanced courses such as Anatomy and Physiology or Advanced Placement courses, these standards provide a conceptual framework upon which to build advanced curriculum.

11. Provide information about the Kansas Science Education Standards to all community members who support science learning, including parents.

12. Participate in teacher development workshops on Kansas Science Education Standards implementation provided by KSDE.

Teaching With Tolerance and Respect

Science studies natural phenomena by formulating explanations that can be tested against the natural world. Some scientific concepts and theories (e.g., blood transfusion, human sexuality, nervous system role in consciousness, cosmological and biological evolution, etc.) may differ from the teachings of a student's religious community or their cultural beliefs. Compelling student belief is inconsistent with the goal of education. Nothing in science or in any other field of knowledge shall be taught as absolute knowledge. A teacher is an important role model for demonstrating respect, sensitivity, and civility. Science teachers should not ridicule, belittle or embarrass a student for expressing an alternative view or belief. Teachers have the opportunity to display and demand tolerance and respect for the diverse ideas, skills, and experiences of all students.

Teaching in the Outdoors

Many Kansans now live in environments where nature seems irrelevant, except as entertainment, and the economy dominates our priorities. Current economic trends are based less on production and more on consumption; so often nature and nature's services are valued less. In some respects, humans at the dawn of the species probably knew more about the natural world than does the average Kansas citizen of today. The rise of civilization and more recent increase in urbanization has been paralleled by decreasing personal contact with the natural world. Despite the fact that we are a part of a highly interconnected web of life, the separation of so many people from direct contact with nature has had enormous consequences. The accumulating research reveals the necessity of contact with nature for healthy child development. Varied experiences in the outdoors make natural processes less abstract and are critical to developing scientific literacy. Two authors who describe the importance of children, youth and young adults having direct experience in the out-of-doors are Gary Paul Nabhan and Stephen Trimble in *The Geography of Childhood: Why Children Need Wild Places* (Beacon Press, 1994) and Richard Louv, in his recent book, *Last Child in the Woods: Saving Our Children from Nature Deficit Disorder* (Algonquin Press, 2005).

Nature of Science

Science is a human activity of systematically seeking natural explanations for what we observe in the world around us. Throughout history people from many cultures have used the methods of science to contribute to scientific knowledge and technological innovations, making science a worldwide enterprise. Scientists test explanations against the natural world, logically integrating observations and tested hypotheses with accepted explanations to gradually build more reliable and accurate understandings of nature. Scientific explanations must be testable and repeatable, and findings must be confirmed through additional observation and experimentation. As it is practiced in the late 20th and early 21st century, science is restricted to explaining only the natural world, using only natural cause. This is because science currently has no tools to test explanations using non-natural (such as supernatural) causes.

It is important to note that science cannot answer all questions. Some questions are simply beyond the parameters of science. Among the conditions that help define the boundaries of scientific explanations are the following:

- *Scientific explanations are based on empirical observations or experiments*. The appeal to authority as a valid explanation does not meet the requirements of science. Observations are based on sense experiences or on an extension of the senses through technology.
- *Scientific explanations assume cause-effect relationships*. Much of science is directed toward determining causal relationships and developing explanations for interactions and linkages between objects, organisms, and events. Distinctions among causality, correlation, coincidence, and contingency separate science from pseudoscience.
- *Scientific explanations are tentative.* Explanations can and do change. There are no scientific truths in an absolute sense.
- *Scientific explanations are historical.* Past explanations are the basis for contemporary explanations, and those, in turn, are the basis for future explanations.
- *Scientific explanations are probabilistic*. The statistical view of nature is evident implicitly or explicitly when stating scientific predictions of phenomena or explaining the likelihood of events in actual situations.
- *Scientific explanations are limited*. Scientific explanations sometimes are limited by technology, for example, the resolving power of microscopes and telescopes. New technologies can result in new fields of inquiry or extend current areas of study. The interactions between technology and advances in molecular biology and the role of technology in planetary explorations serve as examples.
- *Scientific explanations are made public.* Scientists make presentations at scientific meetings or publish in professional journals, making knowledge public and available to other scientists.

Hypothesis, law, and theory are frequently misunderstood terms used in science. A hypothesis is a testable statement about the natural world that can be used to design experiments and to build more complex inferences and explanations. A law is a descriptive generalization based on repeated observations. A theory is a well-substantiated explanation of the natural world that incorporates observations, inferences, laws, well-tested hypotheses and experimental findings to explain a specific aspect of the natural world. Theories drive research because they draw attention to areas where data or understandings are incomplete, suggesting additional directions for research.

Because all scientific explanations depend on observational and experimental confirmation, all scientific knowledge is, in principle, subject to change as additional evidence becomes available and/or as new technologies extends our abilities to explore. This open-endedness of science is its greatest strength, and allows for constant refining and improvement of explanations. Although all scientific knowledge is in principle tentative, science has a high degree of confidence in explanations that have been repeatedly tested and shown to be valid. The effect of these criteria is to ensure that scientific explanations about the world can be modified or abandoned in favor of new explanations if empirical evidence so warrants. The willingness of scientists to change explanations based on evidence, actually results in more reliable information. The early 21st century is a time of quite rapid scientific advancement, characterized by a high rate of both discovery and accumulation of knowledge. Rather then developing "new" theories however, the current explosion of knowledge has greatly expanded the basic and well-accepted principles from physics, chemistry, earth sciences, and biological sciences. Scientists recognize that there will always be new frontiers of science.

Unifying Scientific Concepts and Processes within the Standards

Since early in the 20th century, science is often separated in specific disciplines for study (e.g., physics, chemistry, biology, etc). Nonetheless, students should recognize that broad, unifying concepts and processes exist which cut across traditional scientific disciplines. Five such broad, unifying concepts and processes are embedded within the seven standards. These have been selected from the *National Science Education Standards* because they;

- provide connections between and across traditional scientific disciplines,
- are fundamental and comprehensive,
- can be expressed and experienced in a developmentally appropriate manner in K-12 science education.

The five unifying concepts and processes are:

Systems, Order, and Organization: The world about us is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions in order to investigate nature. The units of investigation can be referred to as systems, where a system is an organized group of related objects or components that form a whole. Systems are categorized as open, closed, or isolated, and can consist of organisms, machines, fundamental particles, galaxies, ideas, numbers, and similar phenomena. Systems have boundaries, components, resources, flow (input and output), and feedback. Order - the behavior of units of matter, objects, organisms, or events in the universe - can be described statistically. Probability is the relative certainty (or uncertainty) that individuals can assign to selected events (happening or not happening) in a specified space or time. In science, reduction of uncertainty occurs through such processes as the development of knowledge about factors influencing objects, organisms, systems, or events; better and more observations; and better explanatory models. Types and levels of organization provide useful ways of thinking about the world. Examples of two types of organization include the periodic table of elements and the classification of organisms. Physical systems can be described at different levels of organization - such as fundamental particles, atoms, and molecules. Living systems also have different levels of organization - for example, cells, tissues, organs, organisms, populations, and communities.

Evidence, Models, and Explanation: Evidence consists of observations and empirical data, and is the basis of scientific explanation. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and have explanatory and predictive power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations. Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements.

Constancy, Change, and Measurement: Although most things are in the process of becoming different - changing - some properties of objects and processes are characterized by constancy (e.g., speed of light, charge of an electron, total mass plus energy in the universe). Changes might occur, for example, in properties of materials, position of objects, phenomena in motion, and form and function of systems. Interactions within and among systems create changes. Changes vary in rate, scale, and pattern, including trends and cycles. Equilibrium is a physical state in which forces and changes occur in opposite and off-setting directions. For example, opposite forces are of the same magnitude, or off-setting changes occur at equal rates. Steady state, balance, and homeostasis also describe equilibrium states. Interacting units of matter tend toward equilibrium states in which the energy is distributed as randomly and uniformly as possible. Changes in systems can be quantified, and evidence for interactions and subsequent change and the formulation of scientific explanations are often clarified through quantitative distinctions - measurement. All measurements are approximations, and the accuracy and precision of measurement depend on equipment, technology, and technique used during observations. Mathematics is essential for accurately measuring change. Different systems of measurement are used for different purposes. Scientists usually use the metric system. An important part of measurement is identifying which system to use. For example a meteorologist might use degrees Fahrenheit when reporting the weather to the public, but in writing scientific reports, the meteorologist would use degrees Celsius.

Patterns of Cumulative Change: Accumulated changes through time, some gradual and some sporadic, account for the present form and function of objects, organisms, and natural systems. The general idea is that the present arises from materials and forms of the past. An example of cumulative change is the formation of galaxies, explained by cosmological theories involving (among other theories) gravitation and the behavior of gasses, and the present diversity of living organisms, explained by the biological theory of evolution, or descent with modification of organisms from common ancestors. The present position of the continents is explained by the theories of continental drift, which involves plate tectonic theory, fossilization, uplift and erosion. Patterns of cumulative change also help to describe the current structure of the universe.

Form and Function: Form and function are complementary aspects of objects, organisms, and systems. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form. Understanding of form and function applies to different levels of organization. Form and function can explain each other.

Overview of K-12 Kansas Science Education Standards

	Science as Inquiry	Physics & Chemistry	Life Science	Earth & Space Science	Science & Technology	Science in Personal & Environmental Perspectives	History & Nature Of Science
Grades K-4	• Skills necessary to do (full) scientific inquiry; plan and conduct a simple investigation	• Properties of objects • Position & motion of objects; forces • Sound • Electricity, & magnetism	• Organisms and their environments • Life cycles of organisms	• Properties of earth materials • Objects in the sky • Changes in earth & weather	• Technological design; problem solving skills • Apply understanding of science & technology	• Personal health; identify health risks • Changes in the environment	• People practice science
Grades 5-7	• Abilities necessary to do scientific inquiry; design and conduct investigations • Asking scientific questions • Understanding about scientific inquiry	• Measuring and describing properties of matter • Changes in properties of matter • Motions & forces • Transfer of energy	• Function of structures in organisms • Reproduction & heredity • Regulation & behavior • Populations & ecosystems ▪ Diversity & adaptations of organisms	• Changes in structure of the Earth system • Past & present earth processes • Components of the solar system • Motion & forces that effect earth/space phenomena	• Abilities of technological design • Understanding about science & technology	• Apply scientific knowledge to personal health • The effect of human activity on resources & the environment • Risks & causes of natural hazards	• Scientific habits of mind • Contributions to science through-out history
Grades 8-12	• Abilities necessary to do scientific inquiry • Applies technology and mathematics to do scientific inquiry	<u>Chemistry</u> • Structure of atoms • Structure & properties of matter • Chemical reactions <u>Physics</u> • Motions & forces • Conservation of mass and energy; 1st & 2nd Laws of Thermodynamics ▪ Interactions of energy & matter	▪ Structure and function of the cell • Molecular and chromosomal basis of heredity • Biological evolution • Interdependence of organisms with physical environment • Matter, energy, & organization in living systems • Behavior of animals • Diversity of structure and function in organisms	▪ Energy in earth subsystems • Interactions of Earth's subsystems • Origin and development of the earth system • Dynamics of the solar system ▪ Organization and development of the universe	▪ Technology is applied science ▪ Abilities of technological design	▪ Human health and nutrition • Population growth • Human populations, natural resources and environmental quality ▪ Natural & human-induced hazards ▪ Science, technology, and society	▪ Science as a human endeavor ▪ Nature of scientific knowledge ▪ Science from historical perspectives