Utah Science Core Curriculum
Earth Systems Science, Biology, Physics and Chemistry

Introduction

Science is a way of knowing, a process for gaining knowledge and understanding of the natural world. The Science Core Curriculum places emphasis on understanding and using skills. Students should be active learners. It is not enough for students to read about science; they must do science. They should observe, inquire, question, formulate and test hypotheses, analyze data, report, and evaluate findings. The students, as scientists, should have hands-on, active experiences throughout the instruction of the science curriculum.

The Science Core describes what students should know and be able to do at the end of each course. It was developed, critiqued, piloted, and revised by a community of Utah science teachers, university science educators, State Office of Education specialists, scientists, expert national consultants, and an advisory committee representing a wide diversity of people from the community. The Core reflects the current philosophy of science education that is expressed in national documents developed by the American Association for the Advancement of Science and the National Academies of Science. This Science Core has the endorsement of the Utah Science Teachers Association. The Core reflects high standards of achievement in science for all students.

Organization of the Science Core

The Core is designed to help teachers organize and deliver instruction. Elements of the Core include the following:

- ✓ Each grade level begins with a brief course description.
- ✓ The INTENDED LEARNING OUTCOMES (ILOs) describe the goals for science skills and attitudes. They are found at the beginning of each grade, and are an integral part of the Core that should be included as part of instruction.
- ✓ The SCIENCE BENCHMARKS describe the science content students should know. Each grade level has three to five Science Benchmarks. The ILOs and Benchmarks intersect in the Standards, Objectives and Indicators.
- ✓ A STANDARD is a broad statement of what students are expected to understand. Several Objectives are listed under each Standard.
- ✓ An OBJECTIVE is a more focused description of what students need to know and be able to do at the completion of instruction. If students have mastered the Objectives associated with a given Standard, they are judged to have mastered that Standard at that grade level. Several Indicators are described for each Objective.
- ✓ An INDICATOR is a measurable or observable student action that enables one to judge whether a student has mastered a particular Objective. Indicators are not meant to be classroom activities, but they can help guide classroom instruction.
- ✓ SCIENCE LANGUAGE STUDENTS SHOULD USE is a list of terms that students and teachers should integrate into their normal daily conversations around science topics. These are **not** vocabulary lists for students to memorize.

Seven Guidelines Were Used in Developing the Science Core

Reflects the Nature of Science: Science is a way of knowing, a process for gaining knowledge and understanding of the natural world. The Core is designed to produce an integrated set of Intended Learning Outcomes (ILOs) for students.

As described in these ILOs, students will:

- Use science process and thinking skills.
- Manifest science interests and attitudes.
- Understand important science concepts and principles.
- Communicate effectively using science language and reasoning.
- Demonstrate awareness of the social and historical aspects of science.
- Understand the nature of science.

Coherent: The Core has been designed so that, wherever possible, the science ideas taught within a particular grade level have a logical and natural connection with each other and with those of earlier grades. Efforts have also been made to select topics and skills that integrate well with one another and with other subject areas appropriate to grade level. In addition, there is an upward articulation of science concepts, skills, and content. This spiraling is intended to prepare students to understand and use more complex science concepts and skills as they advance through their science learning.

Developmentally Appropriate: The Core takes into account the psychological and social readiness of students. It builds from concrete experiences to more abstract understandings. The Core describes science language students should use that is appropriate to their grade level. A more extensive vocabulary should not be emphasized. In the past, many educators may have mistakenly thought that students understood abstract concepts (such as the nature of the atom) because they repeated appropriate names and vocabulary (such as "electron" and "neutron"). The Core resists the temptation to describe abstract concepts at inappropriate grade levels; rather, it focuses on providing experiences with concepts that students can explore and understand in depth to build a foundation for future science learning.

Encourages Good Teaching Practices: It is impossible to accomplish the full intent of the Core by lecturing and having students read from textbooks. The Science Core emphasizes student inquiry. Science process skills are central in each standard. Good science encourages students to gain knowledge by doing science: observing, questioning, exploring, making and testing hypotheses, comparing predictions, evaluating data, and communicating conclusions. The Core is designed to encourage instruction with students working in cooperative groups. Instruction should connect lessons with students' daily lives. The Core directs experiential science instruction for all students, not just those who have traditionally succeeded in science classes. The vignettes listed on the Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science for each of the Core standards provide examples, based on actual practice, that demonstrate that excellent teaching of the Science Core is possible.

Comprehensive: The Science Core does not cover all topics that have traditionally been in the science curriculum; however, it does provide a comprehensive background in science. By emphasizing depth rather than breadth, the Core seeks to empower students rather than intimidate them with a collection of isolated and forgettable facts. Teachers are free to add related concepts and skills, but they are expected to teach all the standards and objectives specified in the Core for their grade level.

Useful and Relevant: This curriculum relates directly to student needs and interests. It is grounded in the natural world in which we live. Relevance of science to other endeavors enables students to transfer skills gained from science instruction into their other school subjects and into their lives outside the classroom.

Encourages Good Assessment Practices: Student achievement of the standards and objectives in this Core is best assessed using a variety of assessment instruments. The purpose of an assessment should be clear to the teacher as it is planned, implemented, and evaluated. Performance tests are particularly appropriate to evaluate student mastery of science processes and problem-solving skills. Teachers should use a variety of classroom assessment approaches in conjunction with standard assessment instruments to inform their instruction. Sample test items, keyed to each Core Standard, may be located on the Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science. Observation of students engaged in science activities is highly recommended as a way to assess students' skills as well as attitudes in science. The nature of the questions posed by students provides important evidence of students' understanding of and interest in science.

Chemistry Core Curriculum

The Chemistry Core Curriculum has two primary goals: (1) students will value and use science as a process of obtaining knowledge based on observable evidence, and (2) students' curiosity will be sustained as they develop the abilities associated with scientific inquiry.

Theme

Chemistry is organized around major concepts of matter, structure, energy, and change. The "Benchmarks" in the chemistry Core emphasize the principles and laws that describe the conservation of matter, changes in the structure of matter, and changes in energy. Substances can be described by their chemical structure or properties. Substances can be made of molecules and these molecules are made of atoms. The properties of water are very different from the properties of hydrogen or oxygen of which it is composed. When parts come together, the whole often has properties that are very different from its parts. The formation of compounds results in a great diversity of matter from a limited number of elements. When matter combines, energy is absorbed or released and matter is rearranged to make new substances with new properties.

The purpose of the Utah Chemistry Core Curriculum is to provide the minimum standards for all students to achieve basic scientific literacy in chemistry. The Core is written with the understanding that individual teachers may choose additional content and activities to meet the needs and interests of their own students.

Inquiry

Good science instruction requires hands-on science investigations in which student inquiry is an important goal. Students in chemistry should design and perform experiments, and value inquiry as the fundamental scientific process. Instruction should encourage students to maintain an open and questioning mind to pose their own questions about objects, events, processes, and results. They should have the opportunity to plan and conduct their own experiments, and come to their own conclusions as they read, observe, compare, describe, infer, and draw conclusions. The results of their experiments need to be compared for reasonableness to multiple sources of information. It is important for students at this age to begin to formalize the processes of science and be able to identify the variables in a formal experiment.

Relevance

Chemistry Core concepts should be integrated with concepts and skills from other curriculum areas. Reading, writing, and mathematics skills should be emphasized as integral to the instruction of science. Personal relevance of science in students' lives is an important part of helping students to value science and should be emphasized at this grade level. Developing students' writing skills in science should be an important part of science instruction in chemistry. Students should regularly write descriptions of their observations and experiments. Lab journals are an effective way to emphasize the importance of writing in science.

Providing opportunities for students to gain insights into science related careers adds to the relevance of science learning. Chemistry provides students with an opportunity to investigate careers in chemistry, environmental science, food science, atomic energy, engineering, and medicine. Resources related to careers in science may be found at the Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science .

Character
Value for honesty, integrity, self-discipline, respect, responsibility, punctuality, dependability, courtesy, cooperation, consideration, and teamwork should be emphasized as an integral part of science learning. These relate to the care of living things, safety and concern for self and others, and environmental stewardship. Honesty in all aspects of research, experimentation, data collection, and reporting is an essential component of science.

Resources for Instruction
This Core was designed using the American Association for the Advancement of Science's *Project 2061: Benchmarks For Science Literacy* and the National Academy of Science's *National Science Education Standards* as guides to determine appropriate content and skills.

The Chemistry Core has many online resources designed to help with classroom instruction. The Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science is an ongoing report of resources available and aligned to the Chemistry Core Curriculum.

Safety Precautions and Appropriate Use and Disposal of Chemical
The hands-on nature of science learning increases the need for teachers to use appropriate precautions in the classroom, laboratory, and field. Proper handling and disposal of chemicals is crucial for safety of students and teacher. Prior to students working in the laboratory they should be required to demonstrate their understanding of safe laboratory practices. It is recommended that teachers use microchemistry techniques where appropriate. It is important that all students understand the rules for a safe classroom and laboratory. Field activities should be well thought out and use appropriate and safe practices. Teachers must adhere to the published guidelines for the proper use and disposal of chemicals in the classroom. These guidelines are available on the Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science.

The Most Important Goal
Science instruction should cultivate and build on students' curiosity and sense of wonder. Effective science instruction engages students in enjoyable learning experiences. Science instruction should be as thrilling an experience for a student as watching the colors change in a chemical reaction or observing the formation of silver crystals on a copper wire in a solution of silver nitrate. Science is not just for those who have traditionally succeeded in the subject, and it is not just for those who will choose science-related careers. In a world of rapidly expanding knowledge and technology, all students must gain the skills they will need to understand and function responsibly and successfully in the world. The Core provides skills in a context that enables students to experience the joy of doing science.

Chemistry Core Curriculum

Science Benchmark

Matter on Earth and in the universe is made of atoms that have structure, mass, and a common origin. The periodic table is used to organize elements by structure. A relationship exists between the chemical behavior and the structure of atoms. The periodic table reflects this relationship. The nucleus of an atom is a tiny fraction of the volume of the atom. Each proton or neutron in the nucleus is nearly 2,000 times the mass of an electron. Electrons move around the nucleus. The modern atomic model has been developed using experimental evidence. Atomic theories describe the behavior of atoms as well as energy changes in the atom. Energy changes in an isolated atom occur only in discrete jumps. Change in structure and composition of the nucleus result in the conversion of matter into energy.

STANDARD I: Students will understand that all matter in the universe has a common origin and is made of atoms, which have structure and can be systematically arranged on the periodic table.

Objective 1: Recognize the origin and distribution of elements in the universe.

a. Identify evidence supporting the assumption that matter in the universe has a common origin.
b. Recognize that all matter in the universe and on earth is composed of the same elements.
c. Identify the distribution of elements in the universe.
d. Compare the occurrence of heavier elements on earth and the universe.

Objective 2: Relate the structure, behavior, and scale of an atom to the particles that compose it.

a. Summarize the major experimental evidence that led to the development of various atomic models, both historical and current.
b. Evaluate the limitations of using models to describe atoms.
c. Discriminate between the relative size, charge, and position of protons, neutrons, and electrons in the atom.
d. Generalize the relationship of proton number to the element's identity.
e. Relate the mass and number of atoms to the gram-sized quantities of matter in a mole.

Objective 3: Correlate atomic structure and the physical and chemical properties of an element to the position of the element on the periodic table.

a. Use the periodic table to correlate the number of protons, neutrons, and electrons in an atom.
b. Compare the number of protons and neutrons in isotopes of the same element.
c. Identify similarities in chemical behavior of elements within a group.
d. Generalize trends in reactivity of elements within a group to trends in other groups.
e. Compare the properties of elements (e.g., metal, nonmetallic, metalloid) based on their position in the periodic table.

STANDARD II: Students will understand the relationship between energy changes in the atom specific to the movement of electrons between energy levels in an atom resulting in the emission or absorption of quantum energy. They will also understand that the emission of high-energy particles results from nuclear changes and that matter can be converted to energy during nuclear reactions.

Objective 1: Evaluate quantum energy changes in the atom in terms of the energy contained in light emissions.

a. Identify the relationship between wavelength and light energy.
b. Examine evidence from the lab indicating that energy is absorbed or released in discrete units when electrons move from one energy level to another.
c. Correlate the energy in a photon to the color of light emitted.
d. After observing spectral emissions in the lab (e.g., flame test, spectrum tubes), identify unknown elements by comparison to known emission spectra.

Objective 2: Evaluate how changes in the nucleus of an atom result in emission of radioactivity.

a. Recognize that radioactive particles and wavelike radiations are products of the decay of an unstable nucleus.
b. Interpret graphical data relating half-life and age of a radioactive substance.
c. Compare the mass, energy, and penetrating power of alpha, beta, and gamma radiation.
d. Compare the strong nuclear force to the amount of energy released in a nuclear reaction and contrast it to the amount of energy released in a chemical reaction.
e. After researching, evaluate and report the effects of nuclear radiation on humans or other organisms.

Science language students should use:	atom, element, nucleus, proton, neutron, electron, isotope, metal, nonmetal, metalloid, malleable, conductive, periodic table, quanta, wavelength, radiation, emit, absorb, spectrum, half-life, fission, fusion, energy level, mole

Science Benchmark

Atoms form bonds with other atoms by transferring or sharing electrons. The arrangement of electrons in an atom, particularly the valence electrons, determines how an atom can interact with other atoms. The types of chemical bonds holding them together determine many of the physical properties of compounds. The formation of compounds results in a great diversity of matter from a limited number of elements.

STANDARD III: Students will understand chemical bonding and the relationship of the type of bonding to the chemical and physical properties of substances.

Objective 1: Analyze the relationship between the valence (outermost) electrons of an atom and the type of bond formed between atoms.

a. Determine the number of valence electrons in atoms using the periodic table.
b. Predict the charge an atom will acquire when it forms an ion by gaining or losing electrons.
c. Predict bond types based on the behavior of valence (outermost) electrons.
d. Compare covalent, ionic, and metallic bonds with respect to electron behavior and relative bond strengths.

Objective 2: Explain that the properties of a compound may be different from those of the elements or compounds from which it is formed.

a. Use a chemical formula to represent the names of elements and numbers of atoms in a compound and recognize that the formula is unique to the specific compound.
b. Compare the physical properties of a compound to the elements that form it.
c. Compare the chemical properties of a compound to the elements that form it.
d. Explain that combining elements in different proportions results in the formation of different compounds with different properties.

Objective 3: Relate the properties of simple compounds to the type of bonding, shape of molecules, and intermolecular forces.

a. Generalize, from investigations, the physical properties (e.g., malleability, conductivity, solubility) of substances with different bond types.
b. Given a model, describe the shape and resulting polarity of water, ammonia, and methane molecules.
c. Identify how intermolecular forces of hydrogen bonds in water affect a variety of physical, chemical, and biological phenomena (e.g., surface tension, capillary action, boiling point).

Science language students should use:	chemical property, physical property, compound, valence electrons, ionic, covalent, malleability, conductivity, solubility, intermolecular, polarity

Science Benchmark

In a chemical reaction new substances are formed as atoms and molecules are rearranged. The concept of atoms explains the conservation of matter, since the number of atoms stays the same in a chemical reaction no matter how they are rearranged; the total mass stays the same. Although energy can be absorbed or released in a chemical reaction, the total amount of energy and matter in it remains constant. Many reactions attain a state of equilibrium. Many ordinary activities, such as baking, involve chemical reactions.

The rate of chemical reactions of atoms and molecules depends upon how often they encounter one another, which is a function of concentration, temperature, and pressure of the reacting materials. Catalysts can be used to change the rate of chemical reactions. Under proper conditions reactions may attain a state of equilibrium.

STANDARD IV: Students will understand that in chemical reactions matter and energy change forms, but the amounts of matter and energy do not change.

Objective 1: Identify evidence of chemical reactions and demonstrate how chemical equations are used to describe them.

a. Generalize evidences of chemical reactions.
b. Compare the properties of reactants to the properties of products in a chemical reaction.
c. Use a chemical equation to describe a simple chemical reaction.
d. Recognize that the number of atoms in a chemical reaction does not change.
e. Determine the molar proportions of the reactants and products in a balanced chemical reaction.
f. Investigate everyday chemical reactions that occur in a student's home (e.g., baking, rusting, bleaching, cleaning).

Objective 2: Analyze evidence for the laws of conservation of mass and conservation of energy in chemical reactions.

a. Using data from quantitative analysis, identify evidence that supports the conservation of mass in a chemical reaction.
b. Use molar relationships in a balanced chemical reaction to predict the mass of product produced in a simple chemical reaction that goes to completion.
c. Report evidence of energy transformations in a chemical reaction.
d. After observing or measuring, classify evidence of temperature change in a chemical reaction as endothermic or exothermic.
e. Using either a constructed or a diagrammed electrochemical cell, describe how electrical energy can be produced in a chemical reaction (e.g., half reaction, electron transfer).
f. Using collected data, report the loss or gain of heat energy in a chemical reaction.

STANDARD V: Students will understand that many factors influence chemical reactions and some reactions can achieve a state of dynamic equilibrium.

Objective 1: Evaluate factors specific to collisions (e.g., temperature, particle size, concentration, and catalysts) that affect the rate of chemical reaction.

a. Design and conduct an investigation of the factors affecting reaction rate and use the findings to generalize the results to other reactions.
b. Use information from graphs to draw warranted conclusions about reaction rates.
c. Correlate frequency and energy of collisions to reaction rate.
d. Identify that catalysts are effective in increasing reaction rates.

Objective 2: Recognize that certain reactions do not convert all reactants to products, but achieve a state of dynamic equilibrium that can be changed.

a. Explain the concept of dynamic equilibrium.
b. Given an equation, identify the effect of adding either product or reactant to a shift in equilibrium.
c. Indicate the effect of a temperature change on the equilibrium, using an equation showing a heat term.

Science language students should use:	chemical reaction, matter, law of conservation of mass, law of conservation of energy, temperature, electrochemical cell, entropy, chemical equation, endothermic, exothermic, heat, rate, catalyst, concentration, collision theory, equilibrium, half reaction

Science Benchmark

Solutions make up many of the ordinary substances encountered in everyday life. The relative amounts of solutes and solvents determine the concentration and the physical properties of a solution. Two important categories of solutions are acids and bases.

STANDARD VI: Students will understand the properties that describe solutions in terms of concentration, solutes, solvents, and the behavior of acids and bases.

Objective 1: Describe factors affecting the process of dissolving and evaluate the effects that changes in concentration have on solutions.

a. Use the terms solute and solvent in describing a solution.
b. Sketch a solution at the particle level.
c. Describe the relative amount of solute particles in concentrated and dilute solutions and express concentration in terms of molarity and molality.
d. Design and conduct an experiment to determine the factors (e.g., agitation, particle size, temperature) affecting the relative rate of dissolution.
e. Relate the concept of parts per million (PPM) to relevant environmental issues found through research.

Objective 2: Summarize the quantitative and qualitative effects of colligative properties on a solution when a solute is added.

a. Identify the colligative properties of a solution.
b. Measure change in boiling and/or freezing point of a solvent when a solute is added.
c. Describe how colligative properties affect the behavior of solutions in everyday applications (e.g., road salt, cold packs, antifreeze).

Objective 3: Differentiate between acids and bases in terms of hydrogen ion concentration.

a. Relate hydrogen ion concentration to pH values and to the terms acidic, basic or neutral.
b. Using an indicator, measure the pH of common household solutions and standard laboratory solutions, and identify them as acids or bases.
c. Determine the concentration of an acid or a base using a simple acid-base titration.
d. Research and report on the uses of acids and bases in industry, agriculture, medicine, mining, manufacturing, or construction.
e. Evaluate mechanisms by which pollutants modify the pH of various environments (e.g., aquatic, atmospheric, soil).

Science language students should use:	solution, solute, solvent, concentration, molarity, percent concentration, colligative property, boiling point, freezing point, acid, base, pH, indicator, titration, hydrogen ion, neutralization, parts per million, concentrated, dilute, dissolve