Iowa Core – Davenport Schools
Priority Essential Concepts and Skills for Chemistry

We believe that the scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes.

Science for All Americans, 1990

Introduction

The need for scientific literacy in today's increasingly technological world, for fundamental reforms in how science is taught, and for well-validated models that districts might emulate are by now well-known and documented. Expressions of concern from business leaders, scientists, and educators have led to national, state, and local initiatives. The Iowa Core Curriculum rose from those concerns. It has been a two-decade process in which the Department of Education initiated conversations and produced a body of work that laid the groundwork for this effort. Each of those early efforts led us closer to the design that would produce the clearest picture and become the most useful. This committee used both national and state level documents in this process. The final standards are drawn from the respected work of the National Research Council's (NRC) National Science Education Standards (NSES). The Iowa Core Curriculum is a common set of expectations designed to clarify and raise expectations for all students. It is a tool for Iowa educators to use to assure that essential subject matter is being taught and essential knowledge and skills are being learned.

As the amount of scientific knowledge expands, the need for ALL students to have a deep understanding of essential concepts increases. Technological advances have made information more readily available and decreased the need to memorize vocabulary and formulas. The scientific community agrees that we should teach fewer concepts at greater depth. The Iowa Core Curriculum of essential concepts and abilities in Science is a rich, yet manageable, set that will give each district a comprehensive model to evaluate local curricula. It moves beyond, as stated in the research report, Taking Science to School (National Research Council, The National Academies. Washington, D.C. 2007) "a focus on the dichotomy between either content knowledge or process skills because content and process are inextricably linked in science. Students who are proficient in science:

1. Know, use, and interpret scientific explanations of the natural world;
2. Generate and evaluate scientific evidence and explanations;
3. Understand the nature and development of scientific knowledge; and
4. Participate productively in scientific practices and discourse.

These strands of proficiency represent learning goals for students as well as a broad framework for curriculum design. They address the knowledge and reasoning skills that students must acquire to be proficient in science and, ultimately, able to participate in society as educated citizens."

The Iowa Core Curriculum for Science reflects the belief that ALL students should experience science through a curriculum that is rigorous, relevant, global in its perspective, collaborative in nature, and connected by strong visible links to other areas of study. This document follows the format and content of NSES in which there are eight categories of standards. Four of the categories — Science as Inquiry, Physical Science, Earth and Space Science, and Life Science — are content specific, while the remaining categories — Science and Technology, Science in Personal and Social Perspectives, and the History and Nature of Science — address the application of knowledge. These remaining standards sets call for students to develop abilities to identify and state a problem, design, implement and evaluate a solution, and they complement the abilities developed in the Science as Inquiry Standards. They also help students develop decision-making skills and understand that science reflects its history and is an ongoing, changing enterprise. As such, these standards should be integrated throughout the four content specific categories stated above. These sets include the following at the 9 – 12 level: Science and Technology — abilities of technological design, and understanding about science and technology; Science in Personal and Social Perspectives — personal and community health, population growth, natural resources, environmental quality, natural and human-induced hazards, and science and technology in local, national, and global changes; History and Nature of Science — science as a human endeavor, nature of scientific knowledge, and historical perspectives (see appendix). Science as Inquiry and the

application standards from the NSES are integrated into the knowledge base by design. The content category of Unifying Concepts and Processes complements the other standards. The concepts and procedures in this category provide students with productive and insightful ways of thinking about and integrating basic ideas that explain the natural and designed world (see appendix for details). These concepts and processes include:

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement
- Evolution and equilibrium
- Form and function

Science is more than a body of knowledge. It is a way of thinking and a way of investigating. Students must have the opportunity to examine the impact science has had, and will continue to have, on the environment and society. These opportunities are the focus of the integrated standards.

The Iowa Core Curriculum for Science emphasizes student inquiry. The depth of understanding required of our students is not possible with lectures, readings, cookbook labs, and plug-and-chug problem solving. Students must be actively investigating: designing experiments, observing, questioning, exploring, making and testing hypotheses, making and comparing predictions, evaluating data, and communicating and defending conclusions. A district's science curriculum cannot align to the Iowa Core Curriculum for Science without including inquiry as a guaranteed and viable, testable component in every science course. The science

instruction should be engaging and relevant for the students. Strong connections between the lessons and the students' daily lives must be made. This core curriculum reflects high standards of science achievement for ALL students and not just those who have traditionally succeeded in science classes.

The challenge is to create an educational system that connects students to the scientific world. The broad range of understandings and skills possessed by students when they enter 9th grade will require a system that is clearly articulated and masterfully implemented from kindergarten through grade 12. Teachers will need support and time to prepare for this challenge. This is a first bold step toward a vision of scientific literacy for all.

Science as Inquiry

Essential Concept and/or Skill: ***Identify questions and concepts that guide scientific investigations.***
Students formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and conceptual understanding of scientific investigations. The key is that the student demonstrates knowledge of the scientific concepts through the investigation.

Essential Concept and/or Skill: ***Design and conduct a scientific investigation.***
Designing and conducting a scientific investigation requires introduction to the major concepts in the area being investigated, proper equipment, safety precautions, assistance with methodological problems, recommendations for use of technologies, clarification of ideas that guide the inquiry, and scientific knowledge obtained from sources other than the actual investigation. The investigation may also require student clarification of the question, method, controls, and variables; student organization and display of data; student revision of methods and explanations; and a public presentation of the results with a critical response from peers. Regardless of the scientific investigation performed, students must use evidence, apply logic, and construct an argument for their proposed explanations.

Essential Concept and/or Skill: ***Uses technology and mathematics to improve investigations and communications.***
A variety of technologies, such as hand tools, measuring instruments, and calculators should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry investigation. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.

Essential Concept and/or Skill: ***Formulates and revises scientific explanations and models using logic and evidence.***
Student inquiries culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation.

Essential Concept and/or Skill: ***Think critically and logically to make the relationships between evidence and explanations.***
Thinking critically about evidence includes deciding what evidence should be used and accounting for anomalous data. Specifically, students review data from a simple experiment, summarize the data, and form a logical argument about the cause-and-effect relationships in the experiment.

Essential Concept and/or Skill: ***Recognize and analyze alternative explanations and predictions.***
This aspect of the standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models are best. In other words, although there may be several plausible explanations, they do not all have equal weight. Students use scientific criteria to find the preferred explanations.

Essential Concept and/or Skill: ***Communicate and defend scientific procedures and explanations.***
Students in school science programs develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.

Essential Concept and/or Skill: ***Use mathematics in all aspects of scientific inquiry.***
Mathematics is essential to asking and answering questions about the natural world. Mathematics can be used to ask questions; to gather, organize, and present data; and to structure convincing explanations.

High School Chemistry

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure of atoms.***

Principles that underlie the concept and/or skill include but are not limited to:

- Atomic structure
  - Matter is made of minute particles called atoms, and atoms are composed of even smaller components.
  - These components have measurable properties, such as mass and electrical charge.
  - Each atom has a positively charged nucleus surrounded by negatively charged electrons.
  - The electric force between the nucleus and electrons holds the atom together.

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure of atoms.***

Principles that underlie the concept and/or skill include but are not limited to:

- Atomic nucleus (composition and size)
- Isotopes (related to relative mass)
  - The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons.
  - When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element.

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure of atoms.***

Principles that underlie the concept and/or skill include but are not limited to:

- Nuclear forces: Fission and Fusion
  - The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart.
  - Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions.
  - Fission is the splitting of a large nucleus into smaller pieces.
  - Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure of atoms.***

Principles that underlie the concept and/or skill include but are not limited to:

- Radioactive isotopes
- Predictable rates of decay
    - Radioactive isotopes are unstable and undergo spontaneous nuclear reactions, emitting particles and/or wavelike radiation.
    - The decay of any one nucleus cannot be predicted, but a large group of identical nuclei decay at a predictable rate.
    - This predictability can be used to estimate the age of materials that contain radioactive isotopes.

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure and properties of matter.***

Principles that underlie the concept and/or skill include but are not limited to:

- Valence electrons
- Chemical bonds
    - Atoms interact with one another by transferring or sharing electrons that are the furthest from the nucleus.
    - These outer electrons govern the chemical properties of the element.

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure and properties of matter.***

Principles that underlie the concept and/or skill include but are not limited to:

- Periodic table
- Periodic trends
    - An element is composed of a single type of atom.
    - When elements are listed in order according to the number of protons (called the atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties.
    - This “Periodic Table” is a consequence of the repeating pattern of outermost electrons and their permitted energies

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure and properties of matter.***

Principles that underlie the concept and/or skill include but are not limited to:

- Molecular and ionic structures
- Physical properties of chemical compounds
  - Bonds between atoms are created when electrons are paired up by being transferred or shared.
  - A substance composed of a single kind of atom is called an element.
  - The atoms may be bonded together into molecules or crystalline solids.
  - A compound is formed when two or more kinds of atoms bind together chemically.

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure and properties of matter.***

Principles that underlie the concept and/or skill include but are not limited to:

- States of matter
- Relationship between pressure and volume of gasses
  - Solids, liquids, and gases differ in the distances and angles between molecules or atoms and, therefore, the energy that binds them together.
  - In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure and properties of matter.***

Principles that underlie the concept and/or skill include but are not limited to:

- Hydrocarbon compounds
  - Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

Essential Concept and/or Skill: ***Understand and apply knowledge of chemical reactions.***

Principles that underlie the concept and/or skill include but are not limited to:

- Conservation of matter
- Common reactions
  - "Chemical reactions" is an essential concept of a world-class secondary science curriculum.
  - Included in "chemical reactions" is the following content: Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles.
  - Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.

Essential Concept and/or Skill: ***Understand and apply knowledge of chemical reactions.***

Principles that underlie the concept and/or skill include but are not limited to:

- Thermochemistry
  - Chemical reactions may release or consume energy.
  - Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light.
  - Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.

Essential Concept and/or Skill: ***Understand and apply knowledge of chemical reactions.***

Principles that underlie the concept and/or skill include but are not limited to:

- Types of reactions
- Acids and bases
- Common reactions in living systems
  - A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms.
  - In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds.
  - Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.

Essential Concept and/or Skill: ***Understand and apply knowledge of chemical reactions.***

Principles that underlie the concept and/or skill include but are not limited to:

- Reaction rates and equilibrium
  - Chemical reactions can take place in time periods ranging from the few femtoseconds (10 – 15 seconds) required for an atom to move a fraction of a chemical bond distance to geologic time scales of billions of years.
  - Reaction rates depend on how often the reacting atoms and molecules encounter one another, the temperature, and the properties—including shape—of the reacting elements.