State of Delaware

Department of Education

Science Content Standards Clarification Document

June, 2006

Dedication
John W. Collette, Ph.D.

The 2006 Delaware Science Content Standards are dedicated to John W. Collette, Ph.D., a visionary leader of science reform in Delaware. As a former chemist and director of the DuPont Center for Collaborative Research and Education, Dr. Collette provided leadership in developing the original science content standards. To implement the standards, he co-wrote a National Science Foundation grant which started the Delaware Science Coalition, providing professional development, materials, and assessment for public education. To ensure that students had the skills and knowledge needed for Delaware's workforce, Dr. Collette worked closely with corporate Delaware through his position as Executive Director of the Foundation for Science and Mathematics Education. Constant evaluation of the program and close attention to student test scores were Dr. Collette's means of ensuring the effectiveness of this model. Dr. Collette served in a leadership capacity on the commission that has provided this newly revised set of Delaware Science Content Standards, leading the way into the future of science education. The excitement of discovering and understanding the natural world is evident in every science classroom, thanks to Dr. Collette for providing the means to make this happen.

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Message from the Design Team Chair

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Thanks go to district science specialists and lead teachers who closely examined each draft, with science staff, and then proposed changes. In this manner, each science teacher in Delaware had an opportunity for input. We now have a new set of revised standards that will ensure a rigorous curriculum for all students as we enter the 21st century.

Science Content Area Standards Clarifications Documents

The Delaware Science Content Standards were adopted by the State Board of Education in June of 1995. The work of the 1995 commission members resulted in a clear, concise document that provided precise direction to educators in preparing our students to become effective, productive citizens. This document continues to be the backbone of the 2006 standards. The Delaware Science Content Standards have been viewed as a living document undergoing revision at the appropriate time. In the time period since 1995, the depth and breadth of science knowledge has increased tremendously, providing an opportunity to examine and reflect on the past standards and suggest specific ways of moving forward to meet the high standards of achievement for ***all*** students. The revision process emphasized participation by leading state educators at the elementary, middle, high school, and university levels as well as community stakeholders from business and industry, and community science education. All revisions are strongly rooted in research, evidence collected from data, best teaching practices, national standards, and expert opinion. It was the direct task of the science committee to evaluate and revise the standards ensuring that they are accessible for all students and in a format that can be easily understood by all teachers. The 2006 standards, together with the enduring understandings, essential questions, and grade level expectations, form the basis of what students are expected to know and be able to do.

Components of the Science Statewide Recommended Curriculum include the following:

- Standard Big Idea Statements
- Enduring understandings
- Essential questions
- Content standards for each grade cluster K-3, 4-5, 6-8, 9-12
- Grade level expectations for each grade K-12
- Model units
- Glossary of terms
- Assessments
- Course syllabi/course descriptions

These components provide direction in how science is to be taught, what students should understand and be able to do, and which evidence should be collected, analyzed, and used to form instruction in meeting the curricular goals. This document is more than a general framework. It represents a specific, clear plan- from the standard level to the individual classroom lessons- for directing teaching and learning.

<u>The Goals of the Science Content Standards are to:</u>

- Establish the knowledge and skills needed by all students to be scientifically literate at different grade levels.
- Guide teachers in planning and implementing learning experiences which assure success for all students.
- Provide a framework for assessment in order to measure how well students have met the standards and hold students to high levels of knowledge and skills.

<u>Rationale for the Science Content Standards</u>

There are eight standards in the Delaware Science Content Standards, each clustered for grades K-3, 4-5, 6-8, and 9-12. These clusters are the grade clusters assessed by the Delaware Student Testing Program (DSTP), are similar to the experiences and certification of teachers, and take into account the organization of schools and the frameworks of other content standards.

The science content standards emphasize the following:

Focus of science standards:	Rather than:
▪ understanding science big ideas and concepts through an integrated approach, increasing in depth and rigor with grade levels	▪ knowing discrete facts ▪ studying separate areas of science ▪ learning the same content over and over again ▪ covering many topics in limited depth
▪ grasping science big ideas and concepts through the understandings and abilities of inquiry	▪ passively receiving knowledge from textbooks and teachers ▪ covering large amounts of content/book pages without regard for student development of understanding through inquiry

The eight standards are in a purposeful order. Standard 1, The Nature and Application of Science and Technology, is the ***foundational*** standard on which all others have been developed. This standard emphasizes learning content through inquiry, the interconnectedness of science, technology, and society, and the history and context of science. The science content standards emphasize the following:

Focus of The Nature and Application of Science and Technology:	Rather than:
▪ using the understandings and abilities of inquiry to investigate scientific phenomena ▪ investigating scientific questions over long periods of time ▪ collecting evidence used in forming an explanation ▪ analyzing data used as evidence in defending the conclusion ▪ going beyond one investigation to conduct further investigations and research in order to develop understanding ▪ communicating the results and ideas to others who compare these results and ideas to their own ▪ using the results of investigations to form new questions and discuss scientific ideas	▪ learning process skills independent of content and/or in isolation from other students ▪ using or learning one process skill at a time, such as graphing ▪ completing activities with predetermined outcomes (to get an answer), all of which fit into the class period time frame ▪ experimenting or completing labs for the sake of experimenting without regard for development of understanding ▪ concluding the investigation with the results rather than going further ▪ concluding the investigation without sharing results or communicating the explanation to others such as in journaling the results without group discussion
▪ understanding the interconnectedness of science, technology, and society, and applying this understanding where applicable	▪ lack of understanding of how scientific knowledge develops as new technology becomes available or how new technology is developed with advances in scientific knowledge
▪ understanding how scientific knowledge has developed over history and the context of its development	▪ lack of understanding of major contributions in science, global interconnectedness, and science as a human endeavor

The content standards for physical (standards 2 and 3), earth (standards 4 and 5), and life (standards 6, 7, and 8) science focus on big ideas and concepts that are important for all students to know.

The eight standards are composed of broad standard statements which communicate the big ideas in the standards. Each content standard is subdivided into strands with concepts that spiral up through the grade clusters and are written in developmentally appropriate ways guided by current educational research and experience. The big ideas and concepts in each standard are central to science education and focus on depth of concepts rather than breadth of facts or topics. All eight content standards comprise what is to be taught, learned, and assessed.

Science Standard 1: Nature and Application of Science and Technology Clarification

Big Idea

Science is a human endeavor involving knowledge learned through inquiring about the natural world. Scientific claims are evaluated and knowledge changes as a result of using the abilities and understandings of inquiry. The pursuit of scientific knowledge is a continuous process involving diverse people throughout history. The practice of science and the development of technology are critical pursuits of our society.

Enduring Understandings

- Scientific inquiry involves asking scientifically-oriented questions, collecting evidence, forming explanations, connecting explanations to scientific knowledge and theory, and communicating and justifying the explanation.
- The development of technology and advancement in science influence and drive each other forward.
- Understanding past processes and contributions is essential in building scientific knowledge.

Essential Questions

- What makes a question scientific? What constitutes evidence? When do you know you have enough evidence? Why is it necessary to justify and communicate an explanation?
- How do science and technology influence each other? How have past scientific contributions influenced current scientific understanding of the world?
- What do we mean in science when we say that we stand on the shoulders of giants?

Standard One details the abilities and understandings of science that are critical for all students. Students develop and use the abilities of scientific inquiry as they acquire knowledge of scientific concepts and ideas. The understandings refer to how scientists study the natural world and how the body of scientific knowledge expands and changes.

Abilities and understandings increase in complexity from one grade cluster to the next, depending upon developmental appropriateness. Although the two appear similar, abilities refer to what students should be able to do, while understandings refer to how and why science knowledge changes with new evidence, the analysis of the evidence, and the modification of prior explanations based on new evidence.

This standard requires the use of process skills combined with scientific knowledge, reasoning, and critical thinking to develop ideas and understandings about the natural world. Using this approach, students use developmentally appropriate reasoning to question how data is gathered, the analysis of data, the discrepancies between data sets of the same experiment, as well as the explanations formed. The explanation is then framed and justified around evidence, which in turn is subject to critical review by others.

Inquiry is an important part of this standard. Inquiry is not the only strategy for teaching science, but is a major part of how science is to be taught and how students are to learn. Inquiry is embedded in all grade levels and involves:

- Engaging students in scientifically oriented questions from which empirical evidence can be gathered and analyzed to form an explanation. These questions should be meaningful and relevant to students and able to be answered based on observations and research, using processes and tools that are manageable and appropriate to the students' level.
- Giving priority to evidence, which is then used to develop an explanation. Through the use of accurate, empirical evidence in forming an explanation, science distinguishes itself from other ways of knowing. Measurements are checked, observations are repeated, and data is questioned in determining what counts as "evidence". Explanations based on myths, superstitions, inspiration, or religious beliefs are not scientific and are therefore NOT a part of the science standards.
- Forming an explanation to answer a scientific question. The explanation is open to criticism, at all grade levels, and requires students to justify their responses. It is in the explanation where students expand their knowledge. Misconceptions about scientific ideas and phenomena may still exist in this new explanation depending upon the developmental level of the student. However, major concepts are revisited and clarified as the student moves through the grade clusters.
- Going beyond the evidence collected to form possible alternative explanations. Students are expected to discuss data with each other, compare results, check findings, and read and apply scientific research/knowledge to the question. This phase of inquiry is ***critical*** for students to go beyond the classroom investigation to the world outside and apply what they have learned to new situations and research other possible explanations.
- Communicating the explanation to others at all grade levels. This can be done through writing, drawing, modeling, acting, speaking, or numerous other methods that are consistent with the objective. Communication must include: the question being investigated, procedures for gathering evidence, the proposed explanation, and new findings from outside investigations and research. Other students should be given the opportunity to ask questions and share their own findings as a solid explanation is formed.

Classroom inquiry varies on a continuum from teacher-directed to student-directed depending upon the student's abilities. However, students do not automatically become self-directed with the advancement of grade levels. The content will often dictate the level of teacher or student involvement in scientific inquiry.

The goal of the standards is to produce scientifically literate students who have the ability to use scientific knowledge to reason and think critically about issues and events in the world around them, and therefore, have the abilities and understandings to make informed decisions.

Science Standard 2: Materials and Their Properties
Clarification

Big Idea
Materials exist throughout our physical world. The structures of materials influence their physical properties, chemical reactivity, and use.

Enduring Understandings
- The structures of materials determine their properties.
- The properties of a mixture are based on the properties of its components.
- When materials interact within a closed system, the total mass of the system remains the same.
- There are several ways in which elements and/or compounds react to form new substances and each reaction involves energy.
- People develop new materials as a response to the needs of society and the pursuit of knowledge. This development may have risks and benefits to humans and the environment.

Essential Questions
- How do properties of materials determine their use? How do the properties and structures of materials determine their uses?
- How can the properties of the components of a mixture be used to separate the mixture? How do the components determine the properties of mixtures?
- How does conservation of mass apply to the interaction of materials in a closed system?
- What determines the type and extent of a chemical reaction?
- How do you know which material is best for a particular product or need? What determines if new materials need to be developed? Why should people consider the risks and benefits before the production of new materials and/or the implementation of a new process?

Strand I: Properties and Structure of Materials
In this strand, students in grades K-3 will observe materials as solids, liquids and gases and will recognize that materials may change from one state to another. Students at this level will also recognize that these materials have observable physical properties (such as color and shape) and will classify the materials according to these properties. In grades 4-5, students investigate and classify materials using more sophisticated physical properties such as electrical conductivity and magnetism. In grades 6-8, students use appropriate tools to investigate physical properties (such as density and solubility) and apply the particle model to describe the behavior of materials in relation to heat energy. In grades 9-12, students learn about elements, compounds and mixtures. Students relate the electron structure of the element to its placement on the periodic table and to the physical and chemical properties of the element. Gas laws (the effects of temperature, pressure and volume changes) are investigated at this level. **Please note that in order to establish a firm foundation of knowledge, it is critical that the particle model at the**

K-8 level be understood prior to the introduction of atoms, molecules, and compounds in grades 9-12.

Strand II: Mixtures and Solutions
Students first investigate mixtures in grades 4-5 by grouping, sorting and separating mixtures. In grades 6-8, students use physical properties to separate the components of mixtures. Students investigate the effect of temperature change and solute concentration on solubility as well as the effect of surface area changes on the rate of solubility of solutes. Students recognize the process of diffusion as it relates to movement of particles and relative concentrations of solutions. Students in grades 9-12 investigate how the properties of solutions (solubility, electrical conductivity, etc.) depend on the relative concentrations of the solute and solvent. They also separate mixtures using techniques based on the chemical and physical properties of the components of the mixture.

Strand III: Conservation of Matter
Students in grades 4-5 show that the total mass of an object remains unchanged when it is broken into smaller parts. In grades 6-8, students show that the mass of materials is conserved when combining different materials even if the materials seem to “disappear” (such as dissolving salt in water). In grades 9-12, students show that matter is conserved in chemical reactions and students learn the importance of balancing chemical equations as matter can neither be created nor destroyed in chemical reactions. Students recognize that changes in mass and energy do occur in nuclear reactions but the total of the mass and energy remains the same.

Strand IV: Chemical Reactions
As elements and compounds are first introduced in grade 9 and chemistry is extremely abstract, chemical reactions are not taught until the 9-12 grade cluster. Reactions types and the resulting energy changes (endothermic and exothermic reactions as well as the effect of catalysts) are taught. Students also learn the importance of polymers (synthetic, semi-synthetic, and natural).

Strand V: Material Technology
At the K-3 grade cluster, students recognize that some materials are better for certain uses than others. In grades 4-5, students learn that that materials used can be recycled or reused so that resources are not wasted and products suit the intended purpose. In grades 6-8, students recognize that choices are often made in the production or use of some materials and that these choices have risks and trade-offs. In grades 9-12, students investigate how materials made in response to society’s needs have both positive and negative impacts on the environment and on society.

Science Standard 3: Energy and Its Effects
Clarification

Big Idea
The flow of energy drives processes of change in all biological, chemical, physical, and geological systems. Energy stored in a variety of sources can be transformed into other energy forms, which influence many facets of our daily lives. The forms of energy involved and the properties of the materials involved influence the nature of the energy transformations and the mechanisms by which energy is transferred. The conservation of energy is a law that can be used to analyze and build understandings of diverse physical and biological systems.

Enduring Understandings
- Energy takes many forms. These forms can be grouped into types of energy that are associated with the motion of mass (kinetic energy) and types of energy associated with the position of mass and with energy fields (potential energy).
- Changes take place because of the transfer of energy. Energy is transferred to matter through the action of forces. Different forces are responsible for the transfer of the different forms of energy.
- Energy readily transforms from one form to another, but these transformations are not always reversible. The details of these transformations depend upon the initial form of the energy and the properties of the materials involved. Energy may transfer into or out of a system and it may change forms, but the total energy cannot change.
- People utilize a variety of resources to meet the basic and specific needs of life. Some of these resources cannot be replaced. Other resources can be replenished or exist in such vast quantities they are in no danger of becoming depleted. Often the energy stored in resources must be transformed into more useful forms and transported over great distances before it can be helpful to us.

Essential Questions
- How do we know that things have energy?
- How can energy be transferred from one material to another? What happens to a material when energy is transferred to it?
- What happens to the energy in a system — where does this energy come from, how is it changed within the system, and where does it ultimately go? How does the flow of energy affect the materials in the system?
- What is a "responsible" use of energy? Are there alternative forms of energy that will serve our needs, or better ways of using traditional forms of energy?

Strand I: Forms and Sources of Energy
Radiant energy, kinetic energy, gravitational and elastic potential energies, heat energy, electrical and chemical energy and nuclear energy are addressed in this strand.

Radiant energy is introduced in grades K-3 when students recognize that energy from the Sun heats and lights the Earth. In grades 4-5 students begin investigations of the components of sunlight (IR, visible, and UV light). Students in grades 6-8 begin investigations of other groups of waves in the electromagnetic spectrum and learn how the characteristics of the waves (wavelength, frequency, amplitude) influence the ability of the waves to carry energy. In grades 9-12 the emphasis shifts to how electromagnetic waves interact with matter and the impact of selective absorption on the Earth's systems. Students learn the properties of wave interference, the particle nature of light, and the study of line spectra.

Heat energy in grades K-3 is identified as the type of energy that warms things. Students in grades 4-5 investigate how heat energy influences temperature changes in substances and can produce changes in physical states. In grades 6-8 students use the particle model to study the true nature of heat energy, its effects on materials and how to distinguish between heat energy and temperature. In grades 9-12 students use their knowledge of heat energy to help explain energy flow in more complicated systems.

Kinetic energy is introduced in K-3 as the energy that air and water have by virtue of their motion. In grades 4-5 students recognize that any moving object has energy because of its motion and they investigate how the speed of an object influences its kinetic energy. In grades 6-8 the 'energy of motion' is first labeled as kinetic energy and students recognize that this is a fundamental form of mechanical energy. Through investigations, they determine (qualitatively) how the mass and speed influence the kinetic energy. In grades 9-12, the investigations lead to a quantitative expression relating the kinetic energy to speed and mass and extend to the kinetic energy of rotating masses.

Potential energy is first introduced in grades 4-5 as the energy stored in a stretched elastic material. In grades 6-8, stored energy is first labeled as potential energy, and investigations of gravitational potential energy establish qualitatively how mass and height influence this form of potential energy. In grades 9-12, investigations lead to quantitative expressions for both elastic and gravitational potential energies.

Mechanical waves are introduced in grades 4-5 as a form of energy associated with vibrating objects. Through investigations involving sound, students observe the physical consequences of changing the frequency and amplitude of vibration. In grades 6-8, students use the particle model to build an understanding of the mechanical wave as a mechanism by which mechanical energy can be transferred through substances. In this context, the students look qualitatively at the impact that the frequency and the amplitude have on the ability of mechanical waves to carry energy. In grades 9-12 the students investigate the selective absorption and interference of mechanical waves and the impact these phenomena have on the Earth's systems.

Electrical energy is identified in grades K-3 as a form of energy that is needed to make tools, appliances, and machines work. In grades 4-5, sources of electrical energy are identified, and students build circuits to deliver electrical energy to devices that are designed to make use of this form of energy. In grades 6-8 the students learn that electric energy is associated with concentrations of electric charge and use models to understand the flow of electrical energy in circuits. In grades 9-12 electrical energy is studied as a form of energy that is heavily used in our everyday lives. At the molecular level electrical energy is referred to as chemical energy and is used to help explain chemical bonds and reactions in living and non-living systems.

Nuclear energy is not formally introduced until grades 9-12 where it is identified as a form of potential energy stored in the nucleus. Students recognize that through nuclear fission, nuclear fusion, and radioactive decay unstable nuclei release energy to become more stable and that this energy can be used to benefit or harm human societies.

Strand II: Forces and the Transfer of Energy
This strand addresses the mechanisms through which energy is transferred from one material to another. The focus is on the role that forces play in transferring energy between objects and the consequences that this has on the motion of the objects, but other mechanisms of energy transfer are also addressed.

Before students can describe how forces change the motion of objects they must first learn to describe motion itself. In grades K-3, students learn ways to describe the position of an object (in front of, behind, etc.) and they recognize and describe how objects move (fast, slow, straight, zig-zag, etc.). In grades 4-5, students make measurements of distance and time to reach qualitative conclusions about the relative speeds of objects. In grades 6-8, students recognize that the position, speed and direction of motion are all needed to describe the motion of an object. Students use graphs to examine the motion of objects moving at constant speed, and calculate the speeds of objects from distance and time measurements. The concept of acceleration is introduced in grades 9-12, where it is recognized as a way to describe the change in an object's motion that results from the action of an unbalanced force.

The effect that forces have on objects is introduced through pushing and pulling forces in grades K-3. Students recognize there is a difference between balanced forces and unbalanced forces and observe how the size of an unbalanced force influences the way an object moves. In grades 4-5, students investigate the effect that the size and direction of an applied force have on how the object's speed changes, and how much it changes. In grades 6-8, students recognize that usually two or more forces act on an object simultaneously and they learn that these forces can support each other or act against each other. Students recognize the effect that balanced forces have on an object's motion and investigate the effects that unbalanced forces have on the motion of objects. The effect that the mass of an object has on its response to an unbalanced force is first addressed in grades 9-12. Students at this grade level investigate the effects of force and mass on the acceleration of objects. Newton's Laws are the focus of investigations that enable students to calculate accelerations to predict the motion of objects that are subject to constant forces.

Forces transfer energy, and this transfer process can also be used to predict changes in the motion of objects. K-3 students recognize that the energy of motion of wind and water can be transferred to other objects, making them move. In grades 4-5 students recognize that stored elastic energy can be transferred (and transformed) to produce motion and in grades 6-8 students investigate the role of force in energy transfer. These students learn how to determine how much energy is transferred when a force pushes on an object through a distance, and use knowledge of this transfer process to help trace the flow of energy in physical systems. In grades 9-12, the transfer of energy by forces is called 'work' for the first time, and students learn to calculate and use computational technologies to determine the work done by constant forces. Students at the 9-12 grade level also recognize that the concept of momentum can be used to predict how forces will affect the motion of objects.

There are important energy transfer mechanisms that do not involve identifiable forces. Energy can be transferred through materials by mechanical waves. Students in grades 4-5 learn that sound waves must mass through substances, and observe that these waves travel differently through solids, liquids and gases. In grades 6-8, students use the particle model to explain how mechanical waves transfer energy without transferring mass and in grades 9-12 students use these concepts to explain the effects of mechanical waves in Earth systems.

The transfer of heat energy is introduced to students in grades K-3 when they observe substances becoming warmer or cooler. In grades 4-5, students observe the effects of heat transfer on the melting/freezing and boiling of water. In grades 6-8, students use the particle model to explain heat transfer by conduction and convection. These students examine the thermal properties of materials and learn that different materials transfer heat energy with varying degrees of effectiveness and that materials respond differently to heat energy gains (or losses). Energy transfer through radiation is introduced in grades 6-8. Students in grades 9-12 study heat transfer by radiation in greater detail and apply these concepts to physical phenomena in a variety of Earth systems.

Students in grades 4-5 recognize that the electrical energy available at outlets has been transferred from electrical power stations that are usually located far from the actual outlet. Through the construction of simple series and parallel circuits these students learn to create paths to transfer electrical energy from batteries to devices. In grades 6-8 students investigate that the design of the circuit (series versus parallel) determines the flow rate of energy through the circuit.

Strand III: Energy Interacting With Materials; the Transformation and Conservation of Energy

The third strand addresses the concept of energy transformations and the Law of Conservation of Energy. This law is a fundamental component of every model used in science, and is systematically developed from grades K through 12. To appreciate that energy is not created and not destroyed, students are first taught that there are different forms of energy (Strand I). Then they learn that energy can be transferred from one object to another (Strand II). Finally, they learn that energy can be transformed from one form to another (Strand III). Using these concepts, students can identify the source of energy that seems to appear from nowhere, and trace where energy (that seems to disappear from a system) actually goes. These ideas are developed throughout the grade levels, and starting in grades 6-8 students practice using these concepts to trace the flow of energy through a variety of physical systems. The Law of the Conservation of Energy is formally presented in grades 9-12, when students use the properties of energy to assist in the analysis of physical systems.

All of the forms of energy addressed by the science standards undergo transformations. As an example of how a particular energy transformation is developed, consider the radiant to heat energy transformation. In grades K-3 students recognize that light energy is transformed into heat energy and investigate this process through temperature measurements. In grades 4-5, students observe light striking different materials and reach conclusions about how well these materials absorb and reflect light. In grades 6-8, these investigations become quantitative, and using graphs of their data, students compare how effectively different materials absorb light. These students learn to trace the radiant energy as it strikes the surface of the material and make qualitative estimates of the fraction of light energy that is transformed to heat energy by the absorption process. In grades 9-12 these investigations are extended to infrared waves and ultraviolet waves, where the reflected and transmitted components are measured and students use energy arguments to estimate the absorbing properties of materials for different electromagnetic waves.

Strand IV: The Production, Consumption and Application of Energy

The goal of this strand is to establish clear links between the principles of energy being investigated and the issues associated with energy use locally, nationally and throughout the world. In grades K-3, students discuss and observe how sunlight and the heat energy obtained from wood can be used to heat homes. They discuss the significance of the fact that trees and the energy that comes from the Sun are forms of energy that are renewable. The students also make observations and discuss how the energy in moving air and water can be transferred to machines that will work for us. In grades 4-5, students identify where the electrical energy used in their homes is generated, and what source(s) of energy are used to generate this electrical energy. Using books, computers and other resources, the students identify the ways natural resources are used to supply the energy needs of their homes, schools and workplaces. Students then report on the current practices in the use of sunlight as an alternative source of energy. In grades 6-8, students research and compare the energy efficiency of everyday appliances. They learn how much energy is typically used by these appliances and how this influences the decision of which model appliance to purchase. Using their more sophisticated understanding of kinetic and potential energy forms, students in grades 6-8 also return to the investigation of sources of alternative energy forms and present the advantages and disadvantages of wind power, tidal and hydroelectric power, and other alternative sources. In grades 9-12, students conduct literature searches to identify the factors that determine the fuel efficiency of cars and trucks and report on the development of alternate fuels for these vehicles. They use their knowledge of chemical reactions and their understanding of nuclear energy to identify the advantages and disadvantages of generating electrical energy in fossil fuel electric power plants and nuclear-fueled electric power plants, and reflect on the possibility of shifting to alternative energy forms to generate electrical energy.

Science Standard 4: Earth in Space
Clarification

Big Idea
Our Solar System is a collection of gravitationally interacting bodies that include Earth and the Moon. Universal principles of gravitation allow predictions regarding the motions of objects within the Galaxy and beyond. Earth's motion, position, and posture account for a variety of cyclic events observable from Earth. While the composition of planets vary considerably, their components and the applicable laws of science are universal. The motions and interactions of objects within the Solar System are consistent with the hypothesis that it emerged from a large disk of gas and dust. Our Solar System is part of the Milky Way Galaxy, which in turn is one of many galaxies in the known Universe.

Enduring Understandings
- There are observable, predictable patterns of movement in the Sun, Earth, and Moon system that account for day/night.
- Observable, predictable patterns of movement in the Sun, Earth, and Moon system are caused by gravitational interaction and powered by energy from the Sun.
- Earth is part of a system that includes other planets.
- Most objects in the Solar System orbit the Sun and have distinctive physical characteristics and orderly motion (grades 6-8) which are a result of their formation and changes over time (grades 9-11).
- The Universe is composed of galaxies, which are composed of Solar Systems, all of which are composed of the same elements and governed by the same laws.
- Technology expands our knowledge of the Earth, Moon, and Sun System.
- Technology expands our knowledge of the Solar System.
- Technology expands our knowledge of the Universe.

Essential Questions
- What predictable, observable patterns occur as a result of the interaction between the Earth, Moon, and Sun? What causes these patterns?
- What is Earth's place in the Solar System? How does Earth's physical characteristics and motion compare to other bodies in the Solar System? How does the Sun influence a planet's physical characteristics and motion?
- Is there an order to the Universe? Explain.
- Technology expands our knowledge of the Earth, Moon, and Sun System. Technology expands our knowledge of the Solar System. Technology expands our knowledge of the Universe.
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Strand I: The Earth/Moon/Sun System
In this strand, students will begin to recognize observable, predictable patterns of movement in the Sun, Moon and Earth in grades K-3. This would include the different shapes of the moon throughout the month and the movement of the Sun across the sky from sunrise to sunset. It is purely observational at these grades. We are not concerned about the distinction between stars and planets nor are we concerned with star names or

different types of stars. In grades 4-5, students use models to demonstrate what causes day/night and rotation of the Earth, and why the Sun and Moon appear to be the same sizes in the sky. Models will also be used to gather evidence for why we see the Sun in different locations in the sky throughout a day. By grades 6-8, students investigate what causes moon phases, sunrise/sunset and moonrise/moonset, and further investigate on day/night and day length using models, computer simulations and other resources. Grade 6-8 students recognize that the patterns of movement in our Solar System are caused by gravitational interaction and powered by energy from the Sun. In grades 6-8, both rotation and revolution of the Earth around the Sun and rotation and revolution of the Moon around the Earth are used to help explain the causes of moonrise/moonset, sunrise/sunset, day/night, and eclipses. Gravity is introduced in 8th grade focusing on weight on different planets, keeping planets and moons in orbit around other celestial objects and how gravity influences tides. In grades 9-12, students investigate how the force of gravity causes tides, the making of spherical stars, and planets and star formation. In grades 9-12, the process of nuclear fusion is explained, as well as the age, temperature and size of our Sun compared to other stars in our galaxy.

Strand II: The Solar System

In grades K-3, students do not study the Solar System. They are simply making observations of objects visible in the day sky. In grades 4-5, students will observe (not construct) some type of model of the Solar System and identify major planets that orbit the Sun (a star visible in the daytime sky). Students will recognize that objects farther away appear smaller; however, scale models are not constructed until 8th grade, when the scale models of the Solar System will include both distances and planet size. From grades 6-8, students will not only research characteristics of planets in our Solar System, but they will also compare and contrast their characteristics. The motion of the objects in our Solar System will be investigated as well as how gravity keeps these objects in orbit around the Sun and influences weight and ability to move and function on the different planets. In grades 9-12, gravity is further investigated to explain tides, how the atmosphere and seas stay fixed to the Earth's surface, how gravity makes spherical stars and planets, and maintains the orbit of the planets and gathering of dust to form stars (nebular material).

Strand III: Stars and Galaxies

In grades K-3, students do not study the stars and galaxies. By grade 4, students recognize that the Sun is a star visible in the day sky. In grades 6-8, students will explore our Solar System and how our Solar System is located within the Milky Way galaxy, which is part of a large number of other galaxies. In grades 9-12, the study of the universe is conducted including the use of light years (great distances between galaxies and stars), elements making up the stars and the Big Bang theory. By grade 12, the influence of gravity and how it makes spherical stars and planets, maintains the orbit of the planets and gathering of dust to form stars (nebular material) will be investigated.

Strand IV: Technology and Application

In grades K-3, students will recognize that binoculars help us see objects better in the sky. By grades 4-5, students begin to identify telescopes, such as the Hubble Space Telescope, and how they are used to examine the objects in our Solar System. By grades 6-8, students recognize the importance of technologies (satellites, space probes, space shuttle, etc.) and people that led to our current understanding of space. Students will recognize spin-offs from the space program that influence our daily lives. By grades 9-12, students will discuss the role of telescopes, computers, spectroscopes, space probes, radio telescopes and other technology to expand our knowledge of not only our Solar System, but other regions in our galaxy and beyond.

Science Standard 5: Earth's Dynamic Systems
Clarification

Big Idea

Earth's dynamic systems are made up of the solid earth (geosphere), the oceans, lakes, rivers, glaciers and ice sheets (hydrosphere), the atmosphere, and organisms (biosphere). Interactions among these spheres have resulted in ongoing changes to the system. Some of these changes can be measured on a human time scale, but others occur so slowly, that they must be inferred from geological evidence.

Enduring Understandings

- Earth's systems can be broken down into individual components which have observable measurable properties.
- Earth's components form systems. These systems continually interact at different rates of time, affecting the Earth locally and globally.
- Technology enables us to better understand Earth's systems. It also allows us to analyze the impact of human activities on Earth's systems and the impact of Earth's systems on human activity.

Essential Questions

- How does understanding the properties of Earth materials and the physical laws that govern their behavior lead to prediction of Earth events?
- How do changes in one part of the Earth system affect other parts of the system? In what ways can Earth processes be explained as interactions among spheres?
- How does technology extend human senses and understanding?

Strand I: Components of the Earth

Students, in grades K-3, begin to observe, describe and later identify Earth materials such as soil, sand, rocks and water. Students begin conducting simple tests to identify, sort and group these earth materials. In grades K-3, students learn that water can be a solid or liquid. In grades 4-5, students continue to examine and describe properties of soil and how these properties affect the way the soil can be eroded and deposited. In grades 4-5, students examine water and how temperature determines the state in which water exists. In grades 6-8, students begin to use tools to identify sedimentary rocks and confirm their age and how they were formed by using relative dating, fossil evidence and rock correlation. Students create models in grades 6-8 to simulate the cycling and availability of water in each of its three states. Students in grades 9-12, explore the rock cycle and the differences between ocean and continental rock. Students learn to classify igneous, sedimentary and metamorphic rocks and explain how they are formed by the processes and agents of weathering and erosion, heat and pressure and melting and cooling.

Strand II: Interactions throughout Earth's Systems

In grades K-3, students observe and collect data on weather conditions and discuss how these conditions impact plant, animal and human activity. In grades 4-5, students continue to observe and collect weather data and compare local weather in Delaware to other locations in the USA and the world. Students use historical and observed data to identify and describe different storm systems that occur in Delaware. This information is further elaborated upon and discussed in greater detail in grade 8. In grades 4-5, students use stream tables to model how water flow creates different landforms (and landforms affect water flow) by erosion and deposition. Students explore how the Earth is constantly changing over long periods of time. In grades 6-8, students describe the cycling of rocks through weathering, erosion and deposition and how these processes are constantly changing the surface of the Earth. Plate tectonics and the evidence to support it is also introduced in grade 6 and later developed in grade 9. In grades 6-8, the water cycle is used to model the circulation of water throughout the Earth's crust, oceans and atmosphere and how heat energy drives this cycle. The particle model is used to explain the packing of particles in solids, liquids and gases. In grades 6-8, the idea of particle movement, density and how the uneven heating and cooling of the Earth's surface influences weather and climate is investigated using real-time data collected from various locations around the world. In grades 9-12, models and simulations are used to demonstrate how plate movement generates volcanic and earthquake activity, as well as how new landforms are created. Students use the Theory of Plate Tectonics to explain how the Earth's surface is continually formed and deformed over time.

Strand III: Technology and Applications

In grades K-5, students begin to use simple tools to observe items in close detail and to collect data. In grades 6-12, students use more sophisticated scientific equipment and become familiar with current technological devices scientists use for making observations and collecting data. This information may be used as evidence to support such things as weather predictions or Plate Tectonic theory.

Science Standard 6: Life Processes
Clarification

Big Idea
The natural world is defined by organisms and life processes which conform to principles regarding conservation and transformation of matter and energy. Living organisms use matter and energy to build their structures and conduct their life processes, and have mechanisms and behaviors to regulate their internal environments and to respond to changes in their surroundings. Knowledge about life processes can be applied to improving human health and well being.

Enduring Understandings
- Living systems, from the organismic to the cellular level, demonstrate the complementary nature of structure and function.
- All organisms transfer matter and convert energy from one form to another. Both matter and energy are necessary to build and maintain structures within the organism.
- Organisms respond to internal and external cues, which allow them to survive.
- Grades K-8: The life processes of organisms are affected by their interactions with each other and their environment, and may be altered by human manipulation.
- Grades 9-12: The health of humans and other organisms is affected by their interactions with each other and their environment, and may be altered by human manipulation.

Essential Questions
- How does structure relate to function in living systems from the cellular to the organismic level?
- How is matter transferred and energy transferred/transformed in living systems?
- How do responses to internal and external cues aid in an organism's survival?
- What can we do to benefit the health of humans and other organisms?

Strand I: Structure/Function Relationship
Students begin examining the relationship between structure and function of living things by making generalized observations of plants and animals in grades K-3. From K-3 on through 9-12, students move from macroscopic knowledge of structure/function to microscopic knowledge of structure/function and in turn, gain an understanding of the flow in science from observations to classification to theories. In high school, students should be taught how organelles function together as a system and not as isolated parts.

Strand II: Matter and Energy Transformations
Students gain an understanding that living things have needs for survival, specifically food and energy. In grades K-3, students learn that the basic needs for survival are air, water, food, space, shelter and light. In grades 4-5, they become aware that plants require energy from the sun and that animals require energy from food. **Students should not be**

held responsible for photosynthetic processes at this point. In grades 6-8, students begin to explore the process of photosynthesis as a means for producing food in plants, as well as cellular respiration in plants AND animals as a means of obtaining the energy found in food. **Students should not be held responsible for the chemical equations for each of these processes, and teachers should not spend a lot of time focusing on chemical reactions at the middle school level.** Rather, students should learn that plants use sunlight, water and carbon dioxide within the chloroplasts to make sugar and release oxygen. Regarding cellular respiration, students should know that oxygen and sugar are needed within the mitochondria to release energy for life processes and that carbon dioxide and water are waste products. In grade 10, students gain a deeper conceptual understanding of photosynthesis and cellular respiration. At this point, students should be responsible for the chemical equations and be able to relate the complementary nature of each process.

Strand III: Regulation and Behavior

Students will learn that organisms react to both external and internal stimuli, and that these responses ultimately lead to stable, homeostatic conditions. In grades K-3, students learn about the senses and how they pick up information from the environment. In grades 4-5, they learn about specific behaviors that result from a response to internal and external cues. In grades 6-8, students build upon this knowledge by learning about how internal systems work to maintain stability. In grade 10, a deeper conceptual knowledge is gained by exploring the basic functions of the nervous, endocrine and immune systems to determine how the human body regulates internal conditions. Students should not be held responsible for specific anatomical and physiological content.

Strand IV: Life Processes and Technology Application

The understanding behind this strand is the environment, including technological advances as manipulated by man, has a direct impact on life processes. In grades K-3, students begin to learn about how technology has resulted in mechanical products that help enhance the senses and safety. In grades 4-5, students learn further how the health of organisms can be improved through the use of manmade products and research. In grades 6-8, students become familiar with how manipulation of environmental factors impacts life processes. In grade 10, students explore how certain drugs can affect the homeostatic functions of the human organism, as well as the applications of biotechnology and its effects on human and environmental health

Science Standard 7: Diversity and Continuity of Living Things
Clarification

Big Idea

The natural world consists of a diversity of organisms that transmit their characteristics to future generations. Living things reproduce, develop, and transmit traits, and theories of evolution explain the unity and diversity of species found on Earth. Knowledge of genetics, reproduction, and development is applied to improve agriculture and human health.

Enduring Understandings

- Organisms reproduce, develop, have predictable life cycles, and pass on heritable traits to their offspring.
- The diversity and changing of life forms over many generations is the result of natural selection, in which organisms with advantageous traits survive, reproduce, and pass those traits to offspring.
- The development of technology has allowed us to apply our knowledge of genetics, reproduction, development and evolution to meet human needs and wants.

Essential Questions

- Grades K-5: Why do offspring resemble their parents?
- Grades 6-8: What are the advantages and disadvantages of different reproductive strategies?
- Grades K-12: How do organisms change as they go through their life cycles?
- Grades K-5: How are organisms of the same kind different from each other? How does this help them reproduce and survive?
- Grades 6-12: How does natural selection encourage inter and intra-specific diversity over time?
- The development of technology has allowed us to apply our knowledge of genetics, reproduction, development and evolution to meet human needs and wants.

Strand I: Reproduction, Heredity and Development

In grades K-3, students begin examining the similarities and differences between offspring and their parents by making generalized observations of plants and animals throughout their life cycles. In Kindergarten, this simply means matching parents to offspring. From grades K-3 through grades 4-5, students explore basic life cycles of plants and animals as birth, growth, development, reproduction and death. In grades 6-8, students begin examining the sub-cellular basis for the continuity of life, including genes, chromosomes and the prediction of the inheritance of traits. Students also recognize that the continuity of life is dependent upon successful reproduction. In grade 10, students gain a deeper conceptual understanding of the transmission of genetic information from parents to offspring and explore how changes in that genetic information ultimately results in the diversity of species.

Strand II: Diversity and Evolution

This strand provides students with a framework for explaining why there are so many different kinds of organisms on Earth, why organisms of distantly related species share biochemical, anatomical, and functional characteristics, why species become extinct and how different kinds of organisms are related to one another. In grades K-3, students observe that there are many different plants and animals living throughout the world. In grades 4-5, students begin to observe the variations between organisms of the same type, and begin to recognize that these variations may provide advantages to these organisms. In grades 6-8, students begin to gain a conceptual knowledge of natural selection by understanding that organisms with beneficial traits survive and pass on their genes to their offspring. In grade 10, students learn that the DNA molecule is the functional unit of the evolutionary process and that variation in traits is inherited. These variations result in selective advantages or disadvantages, therefore resulting in either the survival or the extinction of a species.

Strand III: Technology Applications

Students will learn about the importance of biotechnology in today's world so that they may better understand the molecular basis of heredity and critically evaluate the benefits and risks of these technologies. In grades K-3, students will relate the variety of plants and animals that inhabit the Earth to being able to utilize those plants and animals for food, clothing and shelter. In grades 4-5, students explore the idea of humans being able to manipulate plants in order to better meet human wants and needs. In grades 6-8, students further explore how the knowledge of genetics can be used to selectively breed plant and animal populations to maximize desired outcomes. It is not until 10^{th} grade that students are introduced to detailed genetic modification techniques leading to genetically engineered organisms with traits deemed desirable by humans. In addition, it is in grade 10 when students will learn the "why and how" of using biotechnology to genetically engineer organisms with desirable traits. It is important for students at this level to discuss the ethics surrounding the ability to genetically modify organisms as well.

Science Standard 8: Ecology
Clarification

Big Idea
Organisms are linked to one another in an ecosystem by the flow of energy and the cycling of materials. Humans are an integral part of the natural system and human activities can alter the stability of ecosystems.

Enduring Understandings
- Organisms and their environments are interconnected. Changes in one part of the system will affect other parts of the system.
- Matter needed to sustain life is continually recycled among and between organisms and the environment.
- Energy from the Sun flows irreversibly through ecosystems and is conserved as organisms use and transform it.
- Humans can alter the living and non-living factors within an ecosystem, thereby creating changes to the overall system.

Essential Questions
- How can change in one part of an ecosystem affect change in other parts of the ecosystem?
- How do matter and energy link organisms to each other and their environments?
- Why is sunlight essential to life on Earth?
- How do humans have an impact on the diversity and stability of ecosystems?

Strand I: Interactions within the Environment
This strand helps students formulate an understanding of the interconnectedness between organisms and their environments. In grades K-3, students identify the living and nonliving parts of a given environment and observe how plants and animals can physically change the environment in which they live. In grades 4-5, students explore the interdependence among the living and nonliving parts of ecosystems. In addition, they begin to look at how changes in the environment can positively or negatively impact the organisms within the environment. In grades 6-8, students will learn about the specific interrelationships found between the biotic factors within an ecosystem. They learn that ecosystems interact with other ecosystems, and ecosystems can only support a certain number of populations due to limited resources. In grades 9-12, students gain a deeper conceptual understanding of ecosystem dynamics by investigating biological, chemical, and physical processes.

Strand II: Energy Flow and Material Cycles in the Environment
Students will learn about the flow of energy through an ecosystem as well as how matter can be cycled within the environment. In grades K-3, students begin to look at the interdependence of animals on plants and other animals as a source of food. In grades 4-

5, students expand their understanding of this interdependence by including the basic flow of energy from Sun to plants, plants to animals, and then animals to animals. In addition, students learn that organisms within an ecosystem have different roles (producers, consumers, decomposers) to perpetuate the flow of energy. These are basic food chains. **Students should not be held accountable for any photosynthetic processes at this grade level.** In grades 6-8, students further their knowledge of energy flow to include the transformation of energy from sunlight to a biologically usable form of matter, and the transfer of matter from organism to organism and from organism to environment. Students will create food webs at this point. Students should be held responsible for the conservation of matter at this point. In grades 9-12, the cycling of matter is explored in greater detail. In addition, biomagnification is examined as a consequence of chemical pollution within an ecosystem.

Strand III: Human Impact

In this strand, students will assess the impact of human activities on the cycling of matter and the flow of energy through ecosystems. In grades K-3, students will learn that humans can have an impact on the availability of natural resources. In grades 4-5, students explore ways in which human activity can result in negative environmental consequences. In grades 6-8, students further their understanding of the impact humans can have on the environment and begin to look at how decisions are made regarding the use of our natural resources. In grades 9-12, students analyze the impact of science and technology on human activity and how scientific understanding impacts the environment. Students will understand their roles in this world as living organisms within an ecosystem, consumers, decision makers and problem solvers.