Iowa Core Curriculum
K – 12 Science

Essential Concepts and Skill Sets Details and Examples

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.

Guide to the Iowa Core Curriculum Format

Essential Concept and/or Skill: This area contains the larger essential concept or skill

Principles that Underlie the Concept and/or Skill: This area contains the topic headings (essential concepts and principles that underlie the standard).

Illustration of ***Essential Concept and/or Skill*** in the ICLE's Rigor and Relevance Framework **Note: The quadrants are samples, presented here to illustrate and clarify the expected level of rigor. They DO NOT constitute a curriculum nor will one set provide a sufficient opportunity for students to engage a big idea in science.** • These four quadrants contain example activities for each essential concept. These are samples only and not a complete curriculum. • The four quadrants move from lower to higher rigor and relevance. Higher rigor activities are in quadrants C and D. Higher relevance is illustrated in B and D. • *The Unifying Concepts from NSES weave through each activity. When an activity is a particularly strong exemplar for one unifying concept it is noted at the bottom of the quadrant. Clicking on that notation will link to the NSES document site where the Unifying Concepts are explained in greater depth.	
Quadrant C	**Quadrant D**
Quadrant A	**Quadrant B**

Science as Inquiry

High School (9-12) Details and Examples

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.

Illustration of ***Identify questions and concepts that guide scientific investigations*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Sample water from a variety of streams for nitrate levels before and after a spring rain. Analyze the information and explain what steps are needed to reduce nitrates in water sources. * Constancy and Change	**Quadrant D** When people move from one country to another, cancer rates follow the patterns of the country in which they currently reside. Explain this in terms of environmental factors influence on cancer.
Quadrant A What nutrients are present in the foods I eat? Perform simple nutrient tests on foods to find which basic food molecules are present (proteins, fats, sugars, complex carbohydrates).	**Quadrant B** How do the nutrients in my food compare to the food my Grandmother ate? Examine food labels and nutrient information for foods eaten in one meal. Compare this to a meal that your grandmother ate when she was young. Develop a graphic organizer describing the differences you found and explain the social/economic circumstances surrounding each meal.

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.

Illustration of ***Design and conduct a scientific investigation*** in the ICLE's Rigor and Relevance Framework	
Quadrant C How does temperature or pH affect enzyme activity? Design an experiment to explore the effect of temperature or pH on enzyme activity in a catalyzed food reaction. * Evidence, Models, Explanation	**Quadrant D** Design an experiment to demonstrate how altering the number of secondary consumers in a community changes the community dynamics.
Quadrant A In a lab setting compare diatoms found in diatomaceous earth with current diatoms (can use prepared slides or fresh water samples). How are they similar and how are they different? How have species of diatoms changed over time?	**Quadrant B** Using data collected on your average respiration rate at rest, while walking, and after exercising vigorously for 10 minutes, explain how a recreational scuba diver's oxygen needs differ from a demolition and recovery scuba diver's. Assuming they are both 180 lb males, how would their nutritional needs differ? Be specific. * Systems, Order, Organization

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.

Illustration of ***Recognize and analyze alternative explanations and predictions*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students will compare and contrast fission and fusion in respect to their potential for providing energy for the future.	**Quadrant D** Students will participate in a debate on whether or not nuclear reactors should be abandoned as a source of energy because of the disposal problem for the produced wastes that contain isotopes with half-lives measured in the thousands or hundreds of thousands of years.
Quadrant A Students will trace the development of nuclear energy explaining how each scientist revised the theory.	**Quadrant B** Each student will select on scientist who contributed to the development of nuclear energy and present a well-reasoned argument supporting their contributions as the most significant. They will revise their argument as others present their views and work towards consensus as a class deciding who should be honored as the Father or Mother of atomic energy.

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.

Illustration of ***Communicate and defend scientific procedures and explanations*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Describe how bacterial and viral infectious diseases are transmitted, and explain the roles of sanitation, vaccination and antibiotic medications in the prevention and treatment of infectious diseases.	**Quadrant D** Use knowledge of genetics to produce a pedigree for two dogs and a punnet square to determine the chances that the dog's offspring will exhibit a specific genetic disease. Make a recommendation based on your evidence regarding the benefits and risks of mating these two pets.
Quadrant A Students are asked to describe the current scientific explanation for the origin of the solar system.	**Quadrant B** NASA has a goal of sending "pioneers" to build a base for humans on the moon as a take-off point for future planetary exploration. Students are asked to design a lunar base for future inhabitants based on their knowledge of the moon's properties and basic human needs for survival in such an environment. *Systems, Order and Organization

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.

Essential Concept and/or Skill: ***Identify and generate questions that can be answered through scientific investigations.***
Students should develop the ability to refine and refocus broad and ill-defined questions. An important aspect of this ability consists of clarifying questions and inquiries and directing them toward objects and phenomena that can be described, explained, or predicted by scientific investigations.

Students should develop the ability to connect their questions with scientific ideas, concepts, and quantitative relationships that guide investigations.

Illustration of ***Identify and generate questions that can be answered through scientific investigations*** in the ICLE's Rigor and Relevance Framework	
Quadrant C The teacher asks a scientifically oriented question and students design investigations to seek answers.	**Quadrant D** Students ask scientifically oriented questions, design investigations, and conduct investigations to seek answers.
Quadrant A The teacher asks a scientifically oriented question and tells students how to conduct an investigation to find the answer.	**Quadrant B** Students ask scientifically oriented questions. The teacher tells students how to conduct investigations to seek answers.

Essential Concept and/or Skill: ***Design and conduct different kinds of scientific investigations.***
Students understand that different kinds of questions suggest different kinds of scientific investigations.

Students should develop general abilities such as making systematic observations, taking accurate measurements, and identifying and controlling variables.

Students should develop the ability to clarify ideas that are influencing and guiding their inquiry, and to understand how those ideas compare with current scientific knowledge.

Students formulate questions, design investigations, execute investigations, interpret data, use evidence to generate explanations, propose alternative explanations, and critique explanations and procedures.

Students use appropriate safety procedures when conducting investigations.

Essential Concept and/or Skill: ***Understand that different kinds of questions suggest different kinds of scientific investigations.***
Some investigations involve observing and describing objects, organisms and events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.

Essential Concept and/or Skill: ***Select and use appropriate tools and techniques to gather, analyze and interpret data.***
The use of tools and techniques, including computers, will be guided by the questions asked and the investigations students design. Students should be able to access, gather, store, retrieve, and organize data, using computer hardware and software designed for these purposes.

Essential Concept and/or Skill: ***Incorporate mathematics in scientific inquiry.***
Mathematics is used to gather, organize and present data and to construct convincing explanations.

Essential Concept and/or Skill: ***Use evidence to develop descriptions, explanations, predictions, and models.***
Students should base their explanations on observations and they should be able to differentiate between description and explanation.

Developing explanations establishes connections between the content of science and the contexts in which students develop new knowledge.

Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or are too vast to be changed deliberately, or are potentially dangerous.

Different models can be used to represent the same thing.

Essential Concept and/or Skill: ***Think critically and logically to make the relationships between evidence and explanations.***
Students decide what evidence should be used and develop the ability to account for anomalous data.

Students should be able to review data from an experiment, summarize the data, and form a logical argument between cause and effect relationships.

Students should begin to state some explanations in terms of relationships between two or more variables.

Essential Concept and/or Skill: ***Recognize and analyze alternative explanations and predictions.***
Students should develop the ability to listen to and respect the explanations proposed by other students. They should remain open to and acknowledge different ideas and explanations, be able to accept the skepticism of others, and consider alternative explanations.

Essential Concept and/or Skill: ***Communicate and defend procedures and explanations.***
Students should become competent in communicating experimental methods, describing observations and summarizing the results of investigations. Explanations can be communicated through various methods.

Essential Concept and/or Skill: ***Use appropriate safety procedures when conducting investigations.***

Intermediate (3-5) Details and Example

Essential Concept and/or Skill: ***Identify and generate questions that can be answered through scientific investigations.***
Students ask questions that they can answer with scientific knowledge combined with their own observations.

Students recognize that different questions lead to different types of investigations.

Essential Concept and/or Skill: ***Recognize that scientists perform different types of investigations.***
Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting), depending on the types of questions they want to answer.

Essential Concept and/or Skill: ***Plan and conduct scientific investigations.***
Students should engage in systematic observation, making accurate measurements, and identifying and controlling variables.

Students understand the concept of a fair test.

Students follow appropriate safety procedures when conducting investigations.

Illustration of ***Plan and conduct scientific investigations*** in the ICLE's Rigor and Relevance Framework	
Quadrant C The teacher asks a scientifically oriented question and students design investigations to seek answers.	**Quadrant D** Students ask scientifically oriented questions, design investigations, and conduct investigations to seek answers.
Quadrant A The teacher asks a scientifically oriented question and tells students how to conduct an investigation to find the answer. (Teacher questions, Teacher directs)	**Quadrant B** Students ask scientifically oriented questions. The teacher tells students how to conduct investigations to seek answers. (Students question, Teacher directs)

Essential Concept and/or Skill: ***Use appropriate tools and techniques to gather, process, and analyze data.***
Students enhance their skills with tools such as rulers, thermometers, balances, spring scales, magnifiers and microscopes.

Students are introduced to the use of computers and calculators for conducting investigations.

Students' use of appropriate tools is guided by the questions asked and the investigations students design.

Essential Concept and/or Skill: ***Incorporate mathematics in science inquiries.***
Mathematics is used to gather, organize and present data and to construct convincing explanations.

Essential Concept and/or Skill: ***Use evidence to develop reasonable explanations.***
Students should determine what constitutes evidence.

Students should judge the merits or strengths of the data and information used to make explanations.

Students' explanations should reflect the evidence they have obtained in their investigations.

Students should check their explanations against scientific knowledge, their own experiences, and observations of others.

Essential Concept and/or Skill: ***Communicate scientific procedures and explanations.***
Students should communicate, critique, and analyze their work and the work of other students.

Students should share procedures and explanations through various means of communication.

Essential Concept and/or Skill: ***Follow appropriate safety procedures when conducting investigations.***

Primary (K-2) Details and Example

Essential Concept and/or Skill: ***Ask questions about objects, organisms, and events in the environment.***
Students should answer their questions by seeking information from their own observations, investigations and from reliable sources of scientific information.

Essential Concept and/or Skill: ***Plan and conduct simple investigations.***
In earliest years, investigations are largely based on direct observations. As students develop, they design and conduct simple investigations to answer questions.

It is important to follow appropriate safety procedures when conducting investigations.

Illustration of ***Plan and conduct simple investigations*** in the ICLE's Rigor and Relevance Framework	
Quadrant C The teacher asks a scientifically oriented question and the class designs an investigation to seek answers.	**Quadrant D** The class asks a scientifically oriented question and designs and conducts an investigation to seek answers.
Quadrant A The teacher asks a scientifically oriented question and tells students how to find an answer.	**Quadrant B** Students ask a scientifically oriented question. The teacher designs the investigation used by students to seek an answer.

Essential Concept and/or Skill: ***Use tools to gather data and extend the senses.***
Students use tools such as rulers, thermometers, watches, balances, spring scales, magnifiers and microscopes to extend their senses and their abilities to gather data.

Essential Concept and/or Skill: ***Use mathematics in scientific inquiry.***
Mathematics is used to gather, organize and present data and to construct convincing explanations.

Essential Concept and/or Skill: ***Use data to construct reasonable explanations.***
Students should learn what constitutes evidence.

Students' explanations should reflect the evidence they have obtained.

Science as Inquiry

Essential Concept and/or Skill: ***Communicate investigations and explanations.***

Students should begin to develop the abilities to communicate, critique, and analyze their work and the work of other students.

Students should communicate orally, through writing or through drawings.

Essential Concept and/or Skill: ***Follow appropriate safety procedures when conducting investigations.***

Earth and Space

High School (9-12) Details and Examples

Essential Concept and/or Skill: ***Understand and apply knowledge of energy in the earth system.***

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

- Internal sources of energy
- External sources of energy
- Plate tectonics
- Energy transfer in the atmosphere and ocean

Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the earth's original formation.

The outward transfer of Earth's internal heat drives convection circulation in the mantle that propels the plates comprising the earth's surface across the face of the globe.

Heating of the earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.

Illustration of ***Understand and apply knowledge of energy in the earth system*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students are asked to write an explanation of why earthquakes and volcanic eruptions tend to "cluster" in certain belts and areas of the earth's crust and not in others. They must use their knowledge of convection in the crust and plate tectonics to predict where such disasters might affect North and Central America.	**Quadrant D** At least two major disasters have occurred recently (2004-2005) that were caused by the movement of the earth's plates. Where were these located? How were their causes alike and different? How could these disasters be better predicted, both in scope and location? What recommendations would you provide to government and relief agencies in order for them to be better prepared to serve people's needs before and after such emergencies?
Quadrant A Students are asked to build a model, using different colors of clay, to demonstrate earth plates and plate tectonic movements. *Evidence, Models and Explanation	**Quadrant B** Students are asked to create sketches on a black or white board to describe how convection currents in the mantle drive the movements of tectonic plates on the surface. Use a large beaker of boiling water to help illustrate your sketches if you need. *Evidence, Models and Explanation

Essential Concept and/or Skill: ***Understand and apply knowledge of Geochemical cycles.***

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

- Elements/atoms within Earth reservoirs: Solid Earth, oceans, atmosphere, and organisms
- Movement of elements/atoms between reservoirs

The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on Earth moves among reservoirs in the solid Earth, oceans, atmosphere, and organisms as part of geochemical cycles.

Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.

Illustration of ***Understand and apply knowledge of Geochemical cycles*** in the ICLE's Rigor and Relevance Framework	
Quadrant C The carbon cycle is an important life supporting cycle. Some say the cycle has been shifted to an unbalanced system, one in which the shift has gone toward an overabundance of CO2. Provide information to support or refute this belief.	**Quadrant D** You are a member of a business team charged with developing energy sources that will be used to decrease the emission of carbon dioxide. Respond to the following questions based on this scenario: What energy systems will you select as those to support for development? What are the pros and cons of each method? What are the short-term advantages and disadvantages of each? Long-term advantages/ disadvantages? The feasibility of their uses by developed and developing nations?
Quadrant A Students are asked to use a textbook and/or the internet to compile a list of elements and compounds (ex. water, nitrogen) that may be associated with cycles in the earth-ocean-atmosphere system. *Evolution and Equilibrium	**Quadrant B** Students are asked to choose either the nitrogen or the carbon cycle, draw and label the cycle and explain it to other students using the drawing as a visual aid. Students should be sure to point out the role that humans play in the cycle. *Evidence, Models and Explanation

Essential Concept and/or Skill: ***Understand and apply knowledge of origin and evolution of the earth system.***

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

- Formation of solar system
- Geologic time
- Interactions among hydrosphere, lithosphere and atmosphere
- Life: origin, evolution, and effect on Earth systems

The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 10 to 15 billion years ago. The early Earth was very different from the planet on which we live today.

Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods for measuring geologic time include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed.

Interactions among the solid Earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years.

Evidence for one-celled forms of life—the microbes—extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the earth's atmosphere, which did not originally contain oxygen.

Illustration of ***Understand and apply knowledge of origin and evolution of the earth system*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students are asked to write an explanation of why earthquakes and volcanic eruptions tend to "cluster" in certain belts and areas of the earth's crust and not in others. They must use their knowledge of convection in the crust and plate tectonics to predict where such disasters might affect North and Central America.	**Quadrant D** At least two major disasters have occurred recently (2004-2005) that were caused by the movement of the earth's plates. Where were these located? How were their causes alike and different? How could these disasters be better predicted, both in scope and location? What recommendations would you provide to government and relief agencies in order for them to be better prepared to serve people's needs before and after such emergencies?
Quadrant A Students are asked to build a model, using different colors of clay, to demonstrate earth plates and plate tectonic movements. *Evidence, Models and Explanation	**Quadrant B** Application (B) Students are asked to create sketches on a black or white board to describe how convection currents in the mantle drive the movements of tectonic plates on the surface. Use a large beaker of boiling water to help illustrate your sketches if you need. *Evidence, Models and Explanation

Essential Concept and/or Skill: ***Understand and apply knowledge of origin and evolution of the Universe.***

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

- Age and origin of the universe
- Universe and galaxies
- Star formation

The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state: According to this theory, the universe has been expanding ever since.

Early in the history of the universe, matter—primarily the light atoms hydrogen and helium — clumped together through gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe.

Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.

Illustration of ***Understand and apply knowledge of origin and evolution of the Universe*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students are asked to use a long strip of paper to construct a time line divided into two parts. The first line should show the history of technological aids used by people to observe outer space. Start with visual observation and move on to Galileo's telescope, modern observatories, space-based observatories and other important types of hardware. The second (parallel) line should show the discoveries made as better and different types of technological equipment were put to use. Take a few minutes to show and explain your dual timeline to an adult.	**Quadrant D** You are a NASA official who has been asked to prepare a prioritized list of unmanned projects as not all projects can be funded. Your list should include such things as space-based and land-based optical, X-ray, IR, UV and gamma ray instruments. Be prepared to defend your prioritized list and budget requests before a committee of fellow students and/or adults.
Quadrant A Students are asked to explain the current scientific explanation for the origin of the universe.	**Quadrant B** Students are asked to demonstrate how to set up, align, and use a refracting telescope, a Newtonian reflecting telescope and a star finder. *Form and Function

Middle School (6-8) Details and Example

Essential Concept and/or Skill: ***Understand and apply knowledge of the structure and processes of the earth system and the processes that change the earth and its surface.***
The solid earth consists of layers including a lithosphere; a hot, convecting mantle and a dense metallic core.

Tectonic plates constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, are results of these plate motions.

Land forms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion.

Some changes in the earth can be described as the "rock cycle." Rocks at the earth's surface weather, forming sediments that are buried, then compacted, heated, and often re-crystallized into new rock. Eventually, those new rocks may be brought to the surface by the forces that drive plate motions, and the rock cycle continues.

Soil consists of weathered rocks and decomposed organic matter from dead plants, animals, and bacteria. Soils are often found in layers, with each having a different chemical composition and texture.

Living organisms have played many roles in the earth system, including affecting the composition of the atmosphere, producing some types of rocks, and contributing to the weathering of rocks.

Illustration of ***Understand and apply knowledge of the structure and processes of the earth system and the processes that change the earth and its surface*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students make a fudge recipe and cool half in the refrigerator and half on the counter. They analyze the crystalline structure of each half and compare with types of igneous rock.	**Quadrant D** Students investigate different road materials used to fill potholes and develop a proposal to present to the city council advocating for the road material they consider most advantageous.
Quadrant A Students identify a variety of minerals using standard tests for streak, hardness, cleavage and a rock key.	**Quadrant B** Students are invited to bring a rock sample from outside the classroom. They will then apply the same mineral testing protocol to their own specimen.

Essential Concept and/or Skill: ***Understand and apply knowledge of the water cycle, including consideration of events that impact groundwater quality.***
Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the earth's surface, rises and cools as it rises to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil and in soil and rocks underground.

Water is a solvent. As it passes through the water cycle, especially as it moves on the earth's surface and underground, it dissolves minerals and gases and carries them to the oceans, rivers, and other surface water.

Natural and human forces can contribute to contamination of surface water and groundwater.

Essential Concept and/or Skill: ***Understand and apply knowledge of earth history based on physical evidence.***
The earth processes we see today including erosion, movement of tectonic plates, and changes in atmospheric composition are similar to those that occurred in the past.

Earth history is also influenced by occasional catastrophes such as the impact of an asteroid or a comet.

Fossils provide important evidence of how life and environmental conditions have changed.

Essential Concept and/or Skill: ***Understand and apply knowledge of the earth's atmospheric properties and how they influence weather and climate.***
The atmosphere is a mixture of nitrogen, oxygen, and trace gasses that include water vapor. The atmosphere has different properties at different elevations.

Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate because water in the oceans holds a large amount of heat.

Clouds, formed by the condensation of water vapor, affect weather and climate.

Essential Concept and/or Skill: ***Understand and apply knowledge of the components of our solar system.***
The earth is the third planet from the sun in a system that includes the moon, the sun, seven other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.

Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system. Gravity alone holds us to the earth's surface and explains the phenomena of the tides.

The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day.

Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.

Intermediate (3-5) Details and Example

Essential Concept and/or Skill: ***Understand and apply knowledge of properties and uses of earth materials.***
The different physical and chemical properties of earth materials make them useful in different ways, for example, as building materials, as sources of fuel, or for growing the plants we use as foods.

Illustration of ***Understand and demonstrate knowledge of properties and uses of earth materials*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students use their varied soils to pot small plant cuttings and monitor growth for a month. As a class, students compare the quality of the soils based upon the growth patterns.	**Quadrant D** After going to a greenhouse and talking with the nursery technician, students design an experiment to determine the impact of varying the soil mixture upon a plant of their choice.
Quadrant A Students look at different types of soils and look on the internet to find what is in soils.	**Quadrant B** Students collect two cups of soil from their yards and bring it to school. They look at it through magnifying lenses and describe what they find.

Essential Concept and/or Skill: ***Understand and apply knowledge of processes and changes on or in the earth's land, oceans, and atmosphere.***
The surface of the earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes such as landslides, volcanic eruptions, floods and earthquakes.

Essential Concept and/or Skill: ***Understand and apply knowledge of fossils and the evidence they provide of past life on earth.***
Fossils provide evidence of plants and animals that lived long ago and the nature of the environment at that time.

Essential Concept and/or Skill: ***Understand and apply knowledge of weather and weather patterns.***
Weather is always changing and can be described by measurable quantities such as temperature, wind direction and speed and precipitation.

Large masses of air with certain properties move across the surface of the earth. The movement and interaction of these air masses is used to forecast the weather.

Essential Concept and/or Skill: ***Understand and apply knowledge of the properties, movements, and locations of objects in our solar system.***

Most objects in the solar system are in regular and predictable motion. The rotation of the earth on its axis every 24 hours produces the day-and-night cycle. To people on the earth this turning of the planet makes it seem as though the sun, planets, and stars are orbiting the earth once a day.

The sun **appears** to move across the sky in the same way every day. Its apparent path changes slowly across the seasons.

The moon's orbit around the earth once in about 28 days changes what part of the moon is lighted by the sun and how much of that part can be seen from the earth – the phases of the moon.

Eight planets and many other objects revolve around our Sun in predictable patterns. These planets and objects are composed of varied materials.

Primary (K-2) Details and Example

Essential Concept and/or Skill: ***Understand and apply knowledge of properties of earth materials.***
Earth materials are solid rocks and soils, water and the gases of the atmosphere. The varied materials have different physical and chemical properties.

Soils have properties of color and texture, capacity to retain water, and ability to support the growth of many kinds of plants, including those in our food supply.

Essential Concept and/or Skill: ***Understand and apply knowledge of observable information about daily and seasonal weather conditions.***
Weather changes from day to day and over the seasons.

The sun provides the light and heat necessary to maintain the temperature of the earth.

Illustration of ***Understand and apply knowledge of observable information about daily and seasonal weather conditions*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students compare and contrast their collected weather data with that found on official weather websites. Together they discuss possible reasons for any differences.	**Quadrant D** Students explore correlations between dress and weather. They write weather dress codes to be adopted by the elementary grades.
Quadrant A The teacher records student generated weather vocabulary on an ABC framework and uses those words to create a matching game for students to learn weather vocabulary.	**Quadrant B** Students discuss precipitation. The teacher introduces the GLOBE (Global Learning and Observations to Benefit the Environment) protocol for measuring precipitation and the class collects measurements throughout the remainder of the season.

Essential Concept and/or Skill: ***Understand and apply knowledge of events that have repeating patterns.***
Seasons of the year, day and night are events that are repeated in regular patterns.

The sun's position in the sky can be observed and described.

The sun can only be seen during our daylight hours. We are unable to see the sun at night because of the rotation of the earth.

Physical Science

High School (9-12) Details and Examples

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.

Illustration of ***Understand and apply knowledge of the structure of atoms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students find the length of one oleic acid molecule by spreading a small amount over the surface of water and measuring the diameter of the circle. The oleic acid spreads itself into a one-molecule thick layer in the shape of a VERY flat cylinder.	**Quadrant D** Students create a claims and evidence chart listing the evidence, both modern and historic, that led to the current model of the atom. They will use this chart as a learning tool to link theory as a critical foundation leading to understandings in atomic reactions, chemical bonds, physical properties, or other chemistry concepts and applications.
Quadrant A Students use tools including microscopes to investigate the physical and chemical properties of various materials that provide evidence for the existence and structure of atoms (e.g., crystalline structure of various minerals). *Evidence, Models, and Explanation	**Quadrant B** Students model the importance of indirect evidence in identifying the existence and structure of atoms by determining the size and shape of an unknown object inside a closed container without direct observation (e.g., "obscertainers"). They will then make connections to how this is related to modern science tools (i.e., scanning tunneling microscope and atomic force microscope) that are used for imaging atoms on a surface. *Evidence, Models, and Explanation

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.

Illustration of ***Understand and apply knowledge of the structure of atoms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students create models which identify the charge, component particles, and relative mass of the nucleus (not to scale) of several elements on the periodic table.	**Quadrant D** Students create a visual presentation or a model that would teach the concept of scale particularly related to the relative size of atoms. (reference "Powers of 10") *Evidence, Models, and Explanation
Quadrant A Students explain that elements exist as isotopes, which may be stable or unstable and calculate the atomic mass of an element given the percentages and masses of isotopes of that element.	**Quadrant B** Students use different kinds of beans in an analogy for isotopic and atomic mass by exploring the imaginary macroscopic element "Beanium." Examine and mass the beans; Using data, determine the different isotopes which comprise the element "Beanium," atomic mass of each isotope and the weighted average that would become the atomic mass.

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.

Illustration of ***Understand and apply knowledge of the structure of atoms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students demonstrate a simulation of a chain reaction to introduce the concept of fission and nuclear decay. Students, standing in a grid pattern, will be provided two balls of paper (neutrons). One student will be designated with a ball of paper of a different paper (thermal neutron). This student will begin the reaction by tossing his ball toward the students. When a student is "hit" with any ball, he/she tosses his/her two balls in a random direction and then quickly sits down. The reaction dies when neutrons no longer hit students. Students can repeat the simulation for the case when students are packed closer together.	**Quadrant D** Students debate whether or not nuclear reactors should be abandoned as a source of energy because of the disposal problem for the waste products that contain isotopes with half-lives measured in the thousands or hundreds of thousands of years. Analyze the claims and evidence of their own argument and that of others to refine their thinking on the issue.
Quadrant A Students write nuclear equations describing fission and fusion.	**Quadrant B** Students play a game of nuclear checkers using a piece of graph paper with the Atomic Mass Number on the y-axis and Atomic Number on the x-axis. The y-axis will be numbered from 202 to 238 with the x-axis being numbered from 80 to 95. An unknown element, $^{238}_{92}Q$, represented by a quarter that is placed on the appropriate location on the board, is a heavy nucleus that decays into a series of lighter nuclei. The final daughter product of the series is a stable unknown isotope, $^{206}_{82}D$, represented by a dime. It is placed on the appropriate location on the board. The students trace the path of the resulting daughter products with pennies, being limited to making two types of moves that correspond to alpha and beta decay. Students record all daughter nuclei produced with their atomic masses and atomic numbers and to compare their results with other students. This activity allows students to simulate the decay of U-238

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.

Illustration of ***Understand and apply knowledge of the structure of atoms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students balance chemical equations that involve radioactive isotopes which undergo spontaneous nuclear reactions, indicating that both charge and mass number are conserved.	**Quadrant D** Students construct a model using various types of candy, like M&M's, Skittles, jelly beans, and/or various colors of counting cubes with varying number of dots to represent radioactive atoms and their daughter products. The model will present an effective simulation of nuclear decay. Students then use their model to explain why nuclear waste storage is an environmental concern.
Quadrant A Students explain that unstable isotopes undergo spontaneous nuclear decay, emitting energy or particles and energy. They identify the resulting particles and/or wavelike radiation. They define half-life.	**Quadrant B** Students apply the predictable rate of nuclear decay to estimate the age of archaeological remains and fossils. Students also use a Geiger counter to collect and categorize the types of radiation emitted by common consumer products (i.e., Fiesta plate ware, smoke detectors, lantern mantles).

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.

Illustration of ***Understand and apply knowledge of the structure and properties of matter*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students construct electron dot structures for any randomly chosen element found on the periodic table and use them to determine formulas of possible ionic compounds.	**Quadrant D** Students research and use bonding theory to recommend specific solvents for removal of different types of graffiti on a variety of surfaces in the school. *Form and Function
Quadrant A Students identify the total number of electrons and the number of valence electrons for any randomly chosen element found on the periodic table.	**Quadrant B** Students research how water softeners work and design an experiment to test the effectiveness of a water softener in removing ions from tap water.

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

Illustration of ***Understand and apply knowledge of the structure and properties of matter*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students graph several periodic properties (i.e., electronic structure, electronegativity, first ionization energy) and explain the connection to the pattern they see in the graph to the placement of elements in the periodic table. *Systems, Order, and Organization	**Quadrant D** Students use the periodic table to produce a series of "element trading cards" that they will use to teach periodic trends and chemical safety around the home to younger students. *Systems, Order, and Organization
Quadrant A Students explore the periodic table. They will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. *Systems, Order, and Organization	**Quadrant B** Students apply the patterns seen on the periodic table to design a periodic table of some group of common objects (i.e., vegetables, sports teams, movies, candy, books). Then group items to show trends in vertical columns and horizontal rows. *Systems, Order, and Organization

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.

Illustration of ***Understand and apply knowledge of the structure and properties of matter*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students observe some of the differences in macroscopic properties between ionic and covalent compounds. In particular, they compare solubility in water, solubility in methanol, relative melting points, and solution conductivity.	**Quadrant D** Students use knowledge of ionic, covalent, and polar covalent molecules to explain how the body absorbs vitamins A, E, C, and calcium. They will make a recommendation for what vitamins should be taken in bulk at one time and which should be taken separately over time.
Quadrant A Students use electronegativity values to determine the percent of ionic or covalent character present in a bond between atoms.	**Quadrant B** Students use knowledge of ionic, covalent, and polar covalent molecules to explain how detergents work to remove various types of stains and then perform a test to show how certain stain removers are more effective on nonpolar stains.

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.

Illustration of ***Understand and apply knowledge of the structure and properties of matter*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students conduct an experiment to determine the mathematical relationship between the volume and pressure of air trapped inside a plastic syringe by using a biology gas pressure sensor and computer-based laboratory tools.	**Quadrant D** Students explain what they observe when a few raisins are dropped into a container full of a clear carbonated beverage and relate this phenomena to scuba diving. Why is rule number one in scuba diving that divers are NOT to hold their breath? What are the bends? What do the gas laws have to do with diving?
Quadrant A Students investigate how the volume of a gas changes as its temperature or pressure is altered by conducting a series of experiments. These may involve a flask with a balloon stretched over the opening with the flask placed in containers of hot and cold water, a large closed syringe with a small marshmallow placed inside with the plunger being pulled back and pushed in, etc. They will determine whether the relationship between the variables is inverse or directly proportional.	**Quadrant B** Apply the gas laws to explain what they may expect to observe as a closed metal can of paint stripper sits in the sun. Paint stripper contains chemicals that are usually volatile.

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.

Illustration of ***Understand and apply knowledge of the structure and properties of matter*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students use balls and sticks to construct models of hydrocarbon compounds with specific functional groups (e.g., alcohols, ethers, aldehydes, ketones, esters, amines etc.). *Form and Function	**Quadrant D** Students prepare soap or an aromatic compound in the laboratory and apply their knowledge of organic compounds to explore and explain what part hydrocarbons play in the materials. They will research the costs of making soap on a small scale for sale locally.
Quadrant A Students use balls and sticks to construct models of simple aliphatic, aromatic, and cyclic hydrocarbon compounds.	**Quadrant B** Students create a guide to hydrocarbon compounds and classify common hydrocarbons based on use. They will identify which specific functional groups are found in use categories.

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.

Illustration of ***Understand and apply knowledge of chemical reactions*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students write and balance various reactions that take place students' everyday lives.	**Quadrant D** Students research electrochemical cells and use the information they find to analyze the cost effectiveness of hybrid versus gas engines.
Quadrant A Students identify examples of various types of chemical reactions found in students' everyday lives.	**Quadrant B** Students identify and explain the reactions taking place in a car engine (including catalytic converter and combustion).

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.

Illustration of ***Understand and apply knowledge of chemical reactions*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students experimentally classify solubility as either endothermic or exothermic by measuring temperature increases or decreases in a microscale calorimeter. Using the calorimeter, students will then explore reactions with acids and metals, determine the ÆH for the reaction, and rank those results.	**Quadrant D** Students make and explain how hot and cold packs work using safe and available chemicals and all necessary safety precautions. They make recommendations of how much of each chemical to use to maximize the temperature change and control the cost of the hot or cold pack.
Quadrant A Students develop a definition for endothermic and exothermic reactions and give examples of each.	**Quadrant B** Students use a calorimeter to measure the energy given off by various food items (i.e., peanut) and compare to the calories provided on labels.

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.

Illustration of ***Understand and apply knowledge of chemical reactions*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students predict the products of simple chemical reactions based on reaction types.	**Quadrant D** Students use chemistry to analyze the dangerous reactions (and products produced) that might occur if cleaning products found in most homes are mixed. They will create a plan to communicate findings and issue cautionary statements to residents in their community.
Quadrant A Students define, describe and identify chemical reactions as replacement (single and double), synthesis, or decomposition.	**Quadrant B** Students investigate and classify common chemical reactions they encounter such as rusting, bleaching, and burning.

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.

Illustration of ***Understand and apply knowledge of chemical reactions*** in the ICLE's Rigor and Relevance Framework	
Quadrant C simulation or some other means to model and describe how rates of chemical reactions are related to colliding atoms, ions, and molecules.	**Quadrant D** Students conduct an experiment on the effect of temperature on the light emitted by light sticks and create a brochure that explains the conditions necessary to produce the greatest duration of light from one stick. They will compare their results and collaborate with others to refine their work
Quadrant A Students investigate the effect of temperature on the reaction rate of effervescent antacid tablets placed in containers of water.	**Quadrant B** Students explain how the corrosion reaction of an iron-magnesium alloy with saltwater can help produce a hot meal for individuals, such as soldiers or truck drivers, who want a hot meal but have no place to cook..

Essential Concept and/or Skill: ***Understand and apply knowledge of motions and forces.***

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

- Motions
- Forces
- Newton's Laws

Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F = ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

Illustration of ***Understand and apply knowledge of chemical reactions*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students make predictions and observations of the motion of a dynamics cart moving up and/or down an incline using textual, mathematical, pictorial, and graphical representations with data collected from such tools as ticker tape timers and/or motion detectors with computer or portable interfaces with the appropriate programs. Students analyze and interpret these various representations to describe the motion of the dynamics cart. *Systems, Order, and Organization	**Quadrant D** Students confront a situation in which a recent high school graduate is preparing to go off to her first year of college. The graduate has to make a decision about whether or not her car has enough towing capacity to pull a trailer full of her personal belongings. The students develop a procedure based on evidence so recommendations can be made. Students must identify and consider a number of real-world factors that may impact their recommendations. *Systems, Order, and Organization *Evidence, Models, and Explanation
Quadrant A Students devise and conduct their own experiment to identify variables that impact the acceleration of an object and the resulting relationships between these variables and acceleration. Students construct a mathematical model to describe these relationships and use white boards to share them with the class. *Systems, Order, and Organization *Evidence, Models, and Explanation *Constancy, Change, and Measurement	**Quadrant B** Students apply Newton's laws in designing the safety features for an automobile. *Systems, Order, and Organization

Essential Concept and/or Skill: ***Understand and apply knowledge of motions and forces.***

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

- Gravitation
- Mass versus weight

Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and is inversely proportional to the square of the distance between them.

Illustration of ***Understand and apply knowledge of motions and forces*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students calculate and compare the acceleration due to gravity on various celestial bodies, including the earth, moon, and Jupiter. Using computer simulations from software and/or the Internet, students investigate how the acceleration due to gravity on these celestial bodies impacts the motion of a falling object. *Systems, Order, and Organization	**Quadrant D** Students construct a model bungee jump using rubber bands to investigate what adjustments need to be made for people of different weights to fall the same maximum distance measured from a fixed position on the diving tower. Students use a variety of resources including the Internet to learn how adjustments are accomplished at these jumping stations. *Evidence, Models, and Explanation
Quadrant A Students draw free-body diagrams at various positions to illustrate the forces acting on a "terranaut" in an imaginary situation in which he or she "falls" from one end of a tunnel to the other that goes through the earth. Students assume such a feat is not only possible, but that the "terranaut" would survive such an event.	**Quadrant B** Students construct an accelerometer using a spring or rubber band and fish weights to measure their apparent weight for various situations including riding in a car, on an amusement park ride, in an elevator, or running. *Evidence, Models, and Explanation

Essential Concept and/or Skill: ***Understand and apply knowledge of motions and forces.***

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

- Electric and magnetic forces

The electric force is a universal force that exists between any two charged objects. Opposite charges attract, while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them.

Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules.

Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students understand electric motors and generators.

Illustration of ***Understand and apply knowledge of motions and forces*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students construct electroscopes out of materials such as insulated cups, straws, string, aluminum cans, metallic thread, aluminum foil, golf club tubes, or PVC pipe, and foam to investigate the factors that affect the force between charged objects. *Evidence, Models, and Explanation	**Quadrant D** Students encounter a situation in which a young entrepreneur in the home interior decorating business contracts them to investigate whether a dry process can be created for wallpapering rooms in homes. Many people like to do their own decorating but don't like the mess of liquid glue on the walls and the wallpaper in the process. The entrepreneur has asked the students to conduct research on what combinations of wall surface and paper will give the best results.
Quadrant A Students identify the type of electrical charge on a single tape strip placed on a table surface based on its interactions with other charged objects and the classification used by Benjamin Franklin that there are two kinds of charges. *Systems, Order, and Organization	**Quadrant B** Students identify the personal and community advantages and disadvantages of owning and maintaining a hybrid automobile—one that has an internal combustion engine and one or more electric motors that operate in unison and/or independently.

Essential Concept and/or Skill: ***Understand and apply knowledge of conservation of energy and increase in disorder.***

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

- Types of energy
- Energy transformations
- Conservation of energy

"Conservation of energy and increase in disorder" is an essential concept of a world-class secondary science curriculum. Included in "conservation of energy and increase in disorder" is the following content:
The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.

All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.

Illustration of ***Understand and apply knowledge of conservation of energy and increase in disorder.*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students use the law of conservation of energy to predict the minimum height at which a marble or Hot Wheels car would have to be released from the top of an incline so that it can successfully make a jump from one ramp to another or make it all the way around a loop-the-loop without falling away from the track. *Systems, Order, and Organization *Constancy, Change, and Measurement	**Quadrant D** Students encounter a situation in which a vendor who sells mousetrap car kits approaches them to construct a set of design plans for a working mousetrap car that will soon be available through their online catalog. The vendor has offered a good price for the best design plans for the fastest car— with some stipulations. The mousetrap car must actually move at least 5 meters and plans must include a complete description of the relationship between work and the various energy transformations involved in getting the car to move, as well as a description of the related ideas of forces and motion. As a result, students design and construct a mousetrap car with a set of design plans. *Systems, Order, and Organization *Constancy Change and Measurement
Quadrant A Students investigate the various ways in which a bulb will light using one battery, one bulb, and two wires and describe the various energy transfers that take place. *Systems, Order, and Organization *Constancy, Change, and Measurement	**Quadrant B** Wind turbines generate electrical energy from mechanical energy of the wind. The number of wind turbines being constructed and erected in Iowa has increased in recent years. Students conduct research to identify the various sources of energy for the state and the impact of each on the environment and community health. Students also determine the feasibility of wind turbines meeting the entire energy needs of the state.

Essential Concept and/or Skill: ***Understand and apply knowledge of interactions of energy and matter.***

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

- Wave phenomena
- Energy and matter
- Electromagnetic waves

"Interactions of energy and matter" is an essential concept of a world-class secondary science curriculum. Included in "interactions of energy and matter" is the following content:
Waves, including sound and seismic waves, waves on water, and light waves have energy and can transfer energy when they interact with matter.

Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, X-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Illustration of ***Understand and apply knowledge of interactions of energy and matter*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students design and conduct experiments to determine the speed of sound with and without using a microphone connected to a computer or portable interface with sound analysis software. *Constancy, Change, and Measurement	**Quadrant D** John fails the eye exam during the driver's license application process. During a visit to the optometrist, he finds out that he is nearsighted. He learns he has three options: (1) glasses, (2) contacts, or (3) LASIK eye surgery. Students will research the types of corrective lenses and eye surgery procedure that would be applicable in John's situation. They will also identify factors that may impact John's decision and make recommendations that include an explanation of the related physics principles.
Quadrant A Students explore the properties of transverse and longitudinal waves in strings and springs. They will also use a ripple tank apparatus or a computer simulation of a ripple tank to explore the properties of waves that are generated in water. *Systems, Order, and Organization *Constancy, Change, and Measurement	**Quadrant B** Students use the wave model to explain how a global positioning system (GPS) can be used in wildlife conservation to track animals over large distances. *Evidence, Models, and Explanation

Middle School (6-8) Details and Example

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

- ***elements, compounds, mixtures, and solutions based on the nature of their physical and chemical properties.***
- ***physical and chemical changes and their relationship to the conservation of matter and energy.***

A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.

Chemical elements do not break down during normal laboratory reactions involving such treatments as heating, exposure to electric current, or reaction with acids. There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter.

Essential Concept and/or Skill: ***Understand and apply knowledge of forms of energy and energy transfer.***

Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object- emitted by or scattered from it- must enter the eye.

Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.

The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy form the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Essential Concept and/or Skill: ***Understand and apply knowledge of motions and forces.***

The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.

If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in speed or direction of an object's motion.

Illustration of ***Understand and apply knowledge of motions and forces*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students test paper airplanes with different characteristics (e.g., different masses, different lengths, thrown with different amounts of effort…). Students analyze data and determine which type of plane is best suited for different types of performance.	**Quadrant D** Students construct a restraint system to keep Ken seated on a motion cart during a crash. They will test their restraint system, analyze the results, modify the restraint system and retest. A state trooper (or other qualified person) will assign final safety ratings.
Quadrant A Students make paper airplanes as directed by the teacher and collect data on how far the planes fly.	**Quadrant B** Students view a video of a skateboarder (or someone on a wheeled vehicle) and describe the steps needed to change that vehicle's motion.

Intermediate (3-5) Details and Example

Essential Concept and/or Skill: ***Understand and apply knowledge of how to describe and identify substances based on characteristic properties.***
It may be necessary to use magnification to observe the component parts of some materials.

A substance has characteristic properties. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

The properties of a substance can be measured using tools and technology.

When a new material (compound) is made by chemically combining two or more materials, it has properties that are different from the original materials. For that reason, many different materials can be made from a small number of basic materials.

Essential Concept and/or Skill: ***Understand and apply knowledge of states of matter and changes in states of matter.***
Materials can exist in different states – solid, liquid and gas. Some common materials can be changed from one state to another by heating or cooling.

Essential Concept and/or Skill: ***Understand and apply knowledge of the concept of conservation of mass/matter.***
When something is broken into parts, the parts have the same total mass as the original item.

Essential Concept and/or Skill: ***Understand and apply knowledge of sound, light, electricity, magnetism, and heat.***
Sound is produced when vibrations from objects travel through a medium and are received. Sound can vary in volume. The pitch of a sound can be varied by changing the rate of vibration.

Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by an object.

Electricity in circuits can produce light, heat, sound, and magnetic effects. Electricity can only flow through a closed circuit.

Magnets attract and repel each other and certain kinds of other materials.

Heat can be produced in many ways, such as burning, rubbing, or mixing one substance with another. Heat can move from one object to another by conduction.

Illustration of ***Understand and apply knowledge of sound, light, electricity, magnetism, and heat*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students explore classroom sound centers. They change the pitch produced by each of the objects and explain their procedure.	**Quadrant D** Students create musical instruments and demonstrate how the instruments can be modified to change the pitch and volume.
Quadrant A Students listen to various sounds and group those sounds into categories.	**Quadrant B** Students bring three everyday items from home that they use to create a sound "from percussion," "from a string" and "from moving air."

Essential Concept and/or Skill: ***Understand and apply knowledge of how forces are related to an object's motion.***
The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

Changes in speed or direction of motion are caused by forces. The greater the force, the greater the change in motion. The more massive an object, the less effect a given force will have in changing its motion.

Primary (K-2) Details and Example

Essential Concept and/or Skill: ***Understand and apply knowledge of observable and measurable properties of objects.***
Objects have many observable properties including size, weight, shape, color, temperature and the ability to react with other substances. Those properties can be measured using tools such as rulers, balances and thermometers.

Objects are made of one or more materials.

Objects can be described by the properties of the materials from which they are made. Properties can be used to separate or sort a group of objects or materials.

Essential Concept and/or Skill: ***Understand and apply knowledge of characteristics of liquids and solids.***
Materials can exist in different states – solid, liquid, and gas.

Some common materials, such as water, can be changed from one state to another by heating or cooling.

Essential Concept and/or Skill: ***Understand and apply knowledge of the positions and motions of objects.***
The position of an object can be described by locating it relative to its background.

An object's motion can be described by observing and measuring its position over time.

An object's position or movement can be changed by pushing or pulling.

Illustration of ***Understand and apply knowledge of the positions and motions of objects*** in the ICLE's Rigor and Relevance Framework	
Quadrant C The teacher challenges students to create ramps that allow the spheres to roll following preset criteria.	**Quadrant D** Students design a blueprint and build a "Super Ramp" of their choice.
Quadrant A Students explore ramps by working with materials supplied by the teacher.	**Quadrant B** Teachers lead students on a neighborhood walk to collect and analyze examples of ramps.

Life Science

High School (9-12) Details and Examples

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

Principles that Underlie the Concept and/or Skill:
Structures and functions

- Cell structures underlie functions
- Cell membranes; absorption and diffusion
- Basic cell processes

Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures, notably the nucleus, mitochondria, ribosomes, chloroplasts, and the endoplasmic reticulum. Some cells have external structures facilitating movement (cilia and flagella).

Illustration of ***Understand and apply knowledge of the cell.*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students investigate Elodea cells and potato cubes to describe and analyze the impact of water crossing the cell membrane. Investigate phenolphthalein agar blocks in a slightly basic solution to explain why there is a limit on cell size. Why is a pickle wrinkled? Use arrows to describe the flow of water in and out of the pickle. *Form and Function	**Quadrant D** Students imagine they are salad/garnish chefs in a restaurant. Crisp salads and garnishes (kale, parsley, lettuce, radishes, etc.) are important to both taste and appearance of food. What steps can be taken to ensure the produce retains its garden freshness?
Quadrant A Construct a Venn diagram for specialized cell structures from plant and animal cells. *Systems, Order, and Organization	**Quadrant B** Research various ways cells move and the cell structures by which they move. This can include sperm, bacteria, and protozoa.

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

Principles that Underlie the Concept and/or Skill:
Functions and chemical reactions

- Enzymes catalyze reactions
- Food molecules (macromolecules) break down to provide molecules for synthesis
- Cell respiration breaks down complex molecules to provide energy

Most cell functions involve chemical reactions. Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules. Both breakdown and synthesis are made possible by protein catalysts, called enzymes.

The chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken and new compounds with lower energy bonds are formed. Cells temporarily store this energy in phosphate bonds of a small high-energy compound called ATP.

Note: Degree of depth for cell respiration is not intended to reach the level of glycolysis and Krebs cycle.

Illustration of ***Understand and apply knowledge of the cell*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students design an experiment to explore the effect of temperature or pH on enzyme activity in a catalyzed food reaction. *Evidence, Models, and Explanation	**Quadrant D** Students use Internet research or web quest to explore "The Problem with Pineapple." Develop a "warning label" for a Jell-O recipe to educate consumers about reasons for excluding pineapple in a recipe.
Quadrant A Perform simple nutrient tests on foods to find which basic food molecules are present (proteins, fats, sugars, complex carbohydrates).	**Quadrant B** Examine food labels and nutrient information for foods eaten in one meal. Compare this to a meal that their grandmother ate when she was young. Develop a graphic organizer describing the differences and explain the social/economic circumstances impacting each meal.

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

Principles that Underlie the Concept and/or Skill:
Cells grow and divide

- Cells grow and divide in a cell cycle

Cell regulation allows cells to respond to their environment and to control and coordinate cell growth and division. Environmental factors can influence cell division.

Illustration of ***Understand and apply knowledge of the cell.*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Investigate the unusual features of cancer cells. What goes wrong? How does mitosis fit into this picture? Compare the time line (in minutes) for a normal cell cycle to that of a cancerous cell. How are they different? Which parts of the cell cycle are different?	**Quadrant D** When people move from one country to another, cancer rates follow the patterns of the country in which they currently reside. Explain environmental influences on cancer.
Quadrant A Do a mitosis web quest visiting various Web sites to see excellent microscopic images and animations of mitosis to learn about the various stages. Create a mitosis time line based on the web quest, including the timing between cell divisions (cell cycle clock).	**Quadrant B** Make a YouTube-like educational video sharing information with other students about the different causes of cancer. The video should help the audience recognize categories of cancer causes. *Evidence, Models, and Explanation

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

Principles that Underlie the Concept and/or Skill:
Photosynthesis

- Photosynthesis links sun energy to usable energy
- Basic process of photosynthesis

Plant cells contain chloroplasts as sites of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment.

Illustration of ***Understand and apply knowledge of the cell*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students design and carry out experiments that analyze and explain the effects of light intensity or duration on photosynthesis (i.e., starch or oxygen reproduction). *Evidence, Models, and Explanation	**Quadrant D** Design models of leaf structure that would maximize photosynthesis in a) low light conditions, b) high light conditions, and c) low carbon dioxide atmosphere. *Form and Function
Quadrant A After viewing simulations or animations, students label leaf structures and plant cell structures. Identify products and reactants for the process of photosynthesis and write the simple equation.	**Quadrant B** A coal-fired power plant is built west of a major forest. Consider carbon dioxide emissions and other environmental factors and predict possible effects on the photosynthetic capabilities of the forest.

Essential Concept and/or Skill: ***Understand and apply knowledge of the molecular basis of heredity.***

Principles that Underlie the Concept and/or Skill:

- Genetic information in cells
- DNA structure specifies genetic information in genes
- Genes direct and control protein synthesis
- DNA mutations

In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism). DNA mutations occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Some mutations can be caused by environmental factors.

Illustration of ***Understand and apply knowledge of the molecular basis of heredity*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Analyze a gene sequence and a mutated gene sequence and predict if the mutation will cause a change in a protein. Identify which type of mutation happened. *Constancy and Change	**Quadrant D** Huntington's disease is caused by mutations that are inherited and can be identified by DNA fingerprinting. Debate the right of an insurance company to require genetic testing, thereby obtaining data that indicates future major medical needs by the client versus the person's individual rights.
Quadrant A Students build a simple model of DNA and identify a sequence that could be a "gene." Explain how this sequence determines a protein. Use this DNA to model replication. *Evidence, Models, and Explanation	**Quadrant B** Using examples such as sickle cell anemia, muscular dystrophy, and other human conditions, identify the mutations and their effect on human life. Complete a genetic disease research project and create a presentation to explain diseases.

Essential Concept and/or Skill: ***Understand and apply knowledge of the molecular basis of heredity.***

Principles that Underlie the Concept and/or Skill:
DNA, chromosomes, and sexual reproduction

- DNA forms chromosomes.
- Organisms have two copies of each chromosome.
- Humans have 22 pairs plus two sex chromosomes.
- Sex cells (sperm and egg) transmit genetic information through the processes of meiotic cell division and fertilization.

Each DNA molecule in a cell forms a single chromosome.
Most of the cells in a human contain two copies of each of 22 different chromosomes plus two chromosomes that determine sex: a female contains two X
chromosomes and a male contains one X and one Y. Transmission of genetic information to offspring occurs through meiosis that produces egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual.

Note: Students should understand there are two versions of cell division; one maintains genetic continuity and one allows for genetic variability.

Illustration of ***Understand and apply knowledge of the molecular basis of heredity*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students analyze meiosis and fertilization. Explain the three ways that DNA variability occurs. Use pop bead chromosomes to illustrate. What are the results in humans and plants when an extra chromosome is present or one is missing? Research different cases to see the effects of extra or missing sets of genetic information	**Quadrant D** Americans have a longer life expectancy, and they are choosing to marry and have children at a later age than previous generations. Speculate on the effects this trend could have on the incidence (frequency) of late-acting dominant lethal alleles in the general population.
Quadrant A Students observe a human karyotype. Identify 22 autosomal pairs and two sex chromosomes. Simulate meiosis and fertilization by using pop bead chromosomes of two different color combinations, for example, red and yellow for one person's chromosomes, and blue and green for the other. Compare genetic makeup of offspring to that of parents. *Systems, Order, and Organization	**Quadrant B** What medical technology is involved in gathering cells for karyotype analysis in early pregnancy? What do genetic counselors do?

Essential Concept and/or Skill: ***Understand and apply knowledge of the molecular basis of heredity.***

Principles that Underlie the Concept and/or Skill:
Basic Inheritance Patterns

- Variability occurs as a result of fertilization
- Basic patterns of inheritance can be identified

The fact that an organism is formed from cells that contain two copies of each chromosome, and therefore two copies of each gene, explains many features of heredity, such as how variations that are hidden in one generation can be expressed in the next. Different genes coding for the same feature code for it in different ways thus leading to identifiable patterns in heritable traits. These patterns of inheritance can be identified and predicted.

Illustration of ***Understand and apply knowledge of the molecular basis of heredity*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Conduct a "make a person/baby" activity using multiple traits with different inheritance patterns.	**Quadrant D** Students assume the role of a plant scientist working for a seed corn company. Outline a procedure for breeding corn that will produce high starch content to be used in ethanol production. What traits will be selected and how will they be "crossed" to produce the desired offspring?
Quadrant A Construct punnett squares for all possible parent crosses (AA x AA, AA x Aa, Aa x Aa, aa x aa) for a single human trait (i.e., widow's peak, hitchhikers thumb, etc.) and give the resulting genotypes and phenotypes for each cross.	**Quadrant B** Using simple recessive inherited disorders (i.e., sickle-cell disease, cystic fibrosis, etc.) develop pedigree charts that will demonstrate where the disease is present or absent in successive generations.

Essential Concept and/or Skill: ***Understand and apply knowledge of biological evolution.***

Principles that Underlie the Concept and/or Skill:
Species evolution

- Species evolve over time.
- Evolution is consequence of: population potential, genetic variability, finite resources and environmental selection.

Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, and (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.

Illustration of ***Understand and apply knowledge of biological evolution*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Analyze the results from a butterfly evolution modeling experiment to describe the changes in butterfly coloration with respect to: random mutation, geologic isolation, environmental factors and the flow of alleles in the population. *Evolution and Equilibrium.	**Quadrant D** Students act as an evolutionary biologist. Design an experiment to study a population. List the observations needed to determine changes in a species. Identify the population and its characteristics
Quadrant A Compare pictures of horses and their ancestors from the earliest known horse ancestor to the present. Describe the changes in their appearance as the species changed over time.	**Quadrant B** Write a pro/con paper outlining the use of antibiotics based on the idea of species evolution. Be sure to explain how bacteria change as a result of antibiotic use. *Evidence, Models, and Explanation

Essential Concept and/or Skill: ***Understand and apply knowledge of biological evolution.***

Principles that Underlie the Concept and/or Skill:
Natural Selection

- Natural selection scientifically explains the fossil record.
- Natural selection explains molecular similarity of diverse species.
- Natural selection is a mechanism for evolution leading to organism diversity.

Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms. The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.

Illustration of ***Understand and apply knowledge of biological evolution*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Using the base sequence in genes from several organisms construct a hypothetical evolutionary tree.	**Quadrant D** Design and construct a section of rock strata that would illustrate the order of evolutionary change for an imaginary organism. *Evolution and Equilibrium
Quadrant A Compare the base sequences in genes of organisms in the same family and those of separate families for similarity of DNA. Use "Evolution in Hawaii" a supplement to teaching about evolution and the nature of science from National Academy Press, 2004 (available online).	**Quadrant B** Analyze the changes in skull size and body size in horses from the Eocene to the present? How does natural selection explain the fossil record? *Evolution and Equilibrium

Essential Concept and/or Skill: ***Understand and apply knowledge of biological evolution.***

Principles that Underlie the Concept and/or Skill:
Relations to common ancestor:

- Current diverse species are related by descent from common ancestors.

The millions of different species of plants, animals, and microorganisms that live on Earth today are related by descent from common ancestors.

Illustration of ***Understand and apply knowledge of biological evolution*** in the ICLE's Rigor and Relevance Framework	
Quadrant C If a characteristic is found in bacteria, fungi, pine trees, snakes, and humans, when did it most likely evolve?	**Quadrant D** Given a cladogram of primate evolution, students design an informational brochure to explain the relationships on the cladogram in terms of homology and speciation to class of peers.
Quadrant A Compare the forelimbs (use diagrams) of different vertebrate species. What are the common (homologous) structures? *Evolution and Equilibrium	**Quadrant B** Compare the human skeleton, including skull, with that of a chimpanzee. Describe the differences and similarities. Construct a Venn diagram to illustrate them.

Essential Concept and/or Skill: ***Understand and apply knowledge of biological evolution.***

Principles that Underlie the Concept and/or Skill:
Biological classification

- Biological classification is based on evolutionary relationships.
- Species is the most fundamental classification unit.

Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities in development and DNA sequences which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

Note: This is not to be construed as a review of organisms included in classification categories such as kingdoms and phyla (e.g., is it not a review of all the invertebrates and vertebrates.) Diversity of this nature is included in the Middle School curriculum category "Knowledge of diversity and adaptations of organisms."

Illustration of ***Understand and apply knowledge of biological evolution*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Given a cladogram of Drosophilids, their pictures, and distribution on the Hawaiian islands, students interpret this information and explain how each species is different and how each could have evolved.	**Quadrant D** Review the DNA sequences of various organisms and determine degree of relatedness.
Quadrant A List classification units from the largest (divisions and kingdoms) to the smallest, most fundamental (species) in the Linnean classification system. What is the role of homology in this system? *Evidence, Models, and Explanation	**Quadrant B** Research how the classification system has changed (historically) from two kingdoms to the present system. Why have these changes occurred? How have technological advances changed classification systems? *Systems, Order, and Organization

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of organisms.***

Principles that Underlie the Concept and/or Skill:
Materials cycling

- Atoms and molecules cycle (e.g., carbon, nitrogen, oxygen cycles).

The atoms and molecules on the earth cycle among the living and nonliving components of the biosphere.

Illustration of ***Understand and apply knowledge of the interdependence of organisms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Sample water from a variety of streams for nitrate levels before and after a spring rain. Analyze the information and explain what steps are needed to reduce nitrates in water sources. *Constancy and Change	**Quadrant D** Develop a proposal for Iowa with techniques and practices that could be adopted to reduce nitrates in surface water and groundwater. Use Internet sources to determine your own "carbon footprint."
Quadrant A Diagram a carbon cycle, a nitrogen cycle and an oxygen cycle. How are the carbon and oxygen cycles related? *Systems, Order, and Organization	**Quadrant B** How is burning of fossil fuels related to global carbon dioxide levels? Research effects of high nitrate levels on human health.

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of organisms.***

Principles that Underlie the Concept and/or Skill:

- Energy transformation from producers through levels of consumers and decomposers

Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers. These tropic levels can be illustrated by food chains and food webs.

Illustration of ***Understand and apply knowledge of the interdependence of organisms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Collect data on the number of producers, herbivores, and carnivores found in a 1 square meter quadrant and analyze these numbers in terms of energy loss through the food pyramid.	**Quadrant D** Select a specific community and design a graphic organizer to show how altering the number of secondary consumers in this community changes the community dynamics.
Quadrant A Do a card sort and match the correct organism with the correct trophic level. Construct three different food chains from the organisms found on your cards.	**Quadrant B** Select a meat eaten by humans. Research the steps required to prepare the meat for sale and consumption. Start your process with the sun's energy. Track all of the steps in which there is energy loss. *systems, order, organization

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of organisms.***

Principles that Underlie the Concept and/or Skill:
Organism interrelationships

- Cooperation and competition within ecosystems
- Interrelationships and interdependency lead to long-term stable systems

Organisms both cooperate and compete in ecosystems. The interrelationships and interdependencies of these organisms may generate ecosystems that are stable for hundreds or thousands of years.

Illustration of ***Understand and apply knowledge of the interdependence of organisms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Explain the impact of the introduction of zebra mussels on the native freshwater mussel populations. *Constancy and Change	**Quadrant D** Develop a recommendation for stocking a new pond, including fish species and suggested population numbers.
Quadrant A Do a card sort and match the correct organism with the correct trophic level. Construct three different food chains from the organisms found on your cards.	**Quadrant B** Describe the effect on fish populations of adding a new predator fish species, like large mouth bass or northern pike, to the community.

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of organisms.***

Principles that Underlie the Concept and/or Skill:
Humans modify ecosystems

- Human modification of ecosystems
- Habitat destruction threatens global stability

Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting,
pollution, atmospheric changes, and other factors are threatening current global stability, and if not addressed, ecosystems will be irreversibly affected.

Illustration of ***Understand and apply knowledge of the interdependence of organisms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Utilize a stream table to demonstrate and explain the effects of natural weather occurrences on different land use patterns. *Constancy, Change, and Evidence	**Quadrant D** Determine the stakeholders and role play different perspectives on the global warming issue, evaluating claims and evidence presented by each stakeholder and possible impacts on ecosystems as viewed from each perspective.
Quadrant A List five examples in the community where humans have modified the natural environment.	**Quadrant B** Research a new addition to your town. Calculate the additional run-off created by this addition. Make a list of talking points and attend a city council meeting and speak.

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of matter, energy, and organization of living systems.***

Principles that Underlie the Concept and/or Skill:
Sunlight energy conversion:

- Living systems require continuous energy input.
- Sunlight serves as the original energy source for life.
- Plants photosynthesize, producing building blocks for making macromolecules and storing energy in chemical bonds.
- Cell respiration releases chemical bond energy stored during photosynthesis.

Living systems require a continuous input of energy, derived primarily from the sun, to maintain their chemical and physical organization. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon containing (organic) molecules. These molecules can be used to assemble larger molecules (proteins, DNA, sugars, and fats). The chemical energy stored in bonds between the atoms can be used as sources of energy for life processes.

Note: The cellular mechanisms of photosynthesis and cell respiration are included in "The Cell."

Illustration of ***Understand and apply knowledge of the interdependence of matter, energy, and organization of living systems*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Design, conduct, and analyze an experiment investigating O2 and CO2 production from a variety of organisms: elodea, fish and snail. Describe how their needs vary in light and darkness and explain these differences. Explain the differences between energy production in photosynthetic autotrophs and chemosynthetic autotrophs.	**Quadrant D** Many species grown in the temperate climates have been imported from warmer tropical/subtropical environments. They do not have the capacity to acclimate to cool, much less freezing temperatures. Investigate global climate change predictions and construct several graphs to show the potential impact of global worming on the primary production of corn/soy beans and Iowa's economy.
Quadrant A Construct a graphic organizer that illustrates the conversion of light energy to energy stored in a macromolecule to energy in ATP.	**Quadrant B** Using data collected on average respiration rate at rest, while walking, and after exercising vigorously for 10 minutes, students explain how a recreational scuba diver's oxygen needs differ from a demolition and recovery scuba diver's. Assuming they are both 180- pound males, how would their nutritional needs differ? Be specific. *Systems, Order, Organization

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of matter, energy, and organization of living systems.***

Principles that Underlie the Concept and/or Skill:
Limiting factors:

- Ecosystem and population limiting factors
- Ecosystems have finite resources.
- Environmental factors and finite resources influence ecosystem interactions.

Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy and the ability of the ecosystem to recycle materials.

Illustration of ***Understand and apply knowledge of the interdependence of matter, energy, and organization of living systems*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Conduct the role play "Oh Deer" (from Project WILD) and analyze your results based upon the influence of environmental factors on populations. *Systems, Order, and Organization *Constancy, Change, and Measurement	**Quadrant D** Design a solar space station to be self-sufficient. Discuss what populations would need to be taken aboard. Include all necessary biotic and abiotic factors.
Quadrant A Which element has greatest limiting effect on plant growth?	**Quadrant B** Describe how the Iowa prairie was maintained in the early 1800s. Compare the acreage of prairies in 1850 to that of 1960 to the present. Explain the impact of prairies on Iowa soil.

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of matter, energy, and organization of living systems.***

Principles that Underlie the Concept and/or Skill:
Matter and energy flow and conservation

- Living systems require continuous energy input.
- Matter and energy are conserved as they flow through and between organisms.
- Some energy dissipates into the environment as heat.

All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations.

As matter and energy flows through different levels of organization of living systems—cells, organs, organisms, communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.

Illustration of ***Understand and apply knowledge of the interdependence of matter, energy, and organization of living systems*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Apply the 10% rule for energy transfer to determine relative amounts of primary producers if given the number of tertiary consumers. Predict the number of organisms capable of living on the earth if photosynthesis stops. *Systems, Order, and Organization	**Quadrant D** An alternative form of energy is biomass recycling via burning. Devise a series of graphs that compare the energy provided by burning corn plants versus wheat plants versus burning animal matter.
Quadrant A Explain the concept of conservation of matter and energy.	**Quadrant B** Compare the energy efficiency of ectothermic animals (fish, amphibians, reptiles) to that of endothermic animals (birds and mammals). Design an environment to provide maximum energy efficiency for each. Write a "heat conservation" ad for your environment.

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of the behavior of organisms.***

Principles that Underlie the Concept and/or Skill:
Nervous systems and behavior

- Nerve cell structure and function
- Nerve cell communications through neurotransmitters
- Sensor organs are specialized cells detecting environmental input

Multicellular animals have nervous systems that generate behavior. Nervous systems are formed from specialized cells that conduct signals rapidly through the long cell extensions that make up nerves. The nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules. In sense organs, specialized cells detect light, sound, and specific chemicals and enable animals to monitor what is going on in the world around them.

Illustration of ***Understand and apply knowledge of the interdependence of the behavior of organisms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Explain the relationship of neurotransmitters to Parkinson's disease.	**Quadrant D** Predict new medical technologies that may be designed to correct problems associated with increased volumes and methods of delivery of modern music.
Quadrant A List the four tastes associated with the tongue. Label the structures of a typical neuron. Describe how a synapse works. *Form and Function	**Quadrant B** Discuss the effects of depressants (alcohol) on the nervous system and describe the laws instituted in the United States from 1850 to present to address these effects.

Essential Concept and/or Skill: ***Understand and apply knowledge of the interdependence of the behavior of organisms.***

Principles that Underlie the Concept and/or Skill:
The Human Organism—Basic Functions

- The human immune system protects against microscopic and foreign substances entering the body and from cancer cells arising within.
- The hormonal system exerts its influence by chemicals circulating in the blood.
- Coordinated systems (nervous, muscular and bone) are necessary for locomotion.

Note: The broad topic of Human Biology is integrated into different areas of the middle school and high school curricula, thus some human body systems are omitted from this curriculum.

Illustration of ***Understand and apply knowledge of the interdependence of the behavior of organisms*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Identify the knee or elbow joint as a type I, II, or III lever. Explain how bones, muscles, ligaments and tendons function together for movement. *Form and Function	**Quadrant D** If a diabetic goes into diabetic shock describe the treatment differences for Type I and Type II diabetes. Develop a brochure aimed at educating teachers to recognize and treat the different types of diabetic shock.
Quadrant A List the cells and organs involved in immune system responses. *System, Order, and Organization	**Quadrant B** Research the mechanism and effect of Novocain function for pain relief and other actions.

Middle School (6-8) Details and Example

Essential Concept and/or Skill: ***Understand and apply knowledge of the basic components and functions of cells, tissues, organs, and organ systems.***
Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.

All organisms are composed of cells. Most organisms are single cells; other organisms, including humans are multi-cellular.

Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organism needs.

Specialized cells perform specialized functions in multi-cellular organisms. Groups of specialized cells cooperate to form a tissue, such as muscle. Different tissues are, in turn, grouped together to form larger functional units, called organs. Each type of cell, tissue, and organ has a distinct structure and set of functions that serve the organism as a whole.

Essential Concept and/or Skill: ***Understand and apply knowledge of how different organisms pass on traits (heredity).***
Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.

Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.

The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment.

Essential Concept and/or Skill: ***Understand and apply knowledge of the complementary nature of structure and function and the commonalities among organisms.***
Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems. Organisms are classified according to common characteristics.

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

- ***interdependency of organisms, changes in environmental conditions, and survival of individuals and species.***
- ***the cycling of matter and energy in ecosystems.***

All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment.

Regulation of an organism's internal environment involves sensing the internal environment and changing physiological activities to keep conditions within the range required to survive.

Behavior is one kind of response an organism can make to an internal or environmental stimulus. A behavioral response requires coordination and communication on many levels, including cells, organ systems, and whole organisms. Behavioral response is a set of actions determined in part by heredity and in part from experience.

Species acquire many of their unique characteristics through biological adaptation which involves the selection of naturally occurring variations in populations.

Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.

For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.

Illustration of ***Understand and apply knowledge of:*** • ***interdependency of organisms, changes in environmental conditions, and survival of individuals and species.*** • ***the cycling of matter and energy in ecosystems.*** in the ICLE's Rigor and Relevance Framework	
Quadrant C Students investigate how an invasive species would affect a food web.	**Quadrant D** Students design and construct a working ecosystem in a two liter bottle. They collect data on how well it functions.
Quadrant A Given a list of organisms, students construct a food web.	**Quadrant B** Students interview a local naturalist about the presence of zebra mussels in Iowa.

Essential Concept and/or Skill: ***Understand and demonstrate knowledge of the social and personal implications of environmental issues.***
Chapter 12 of the Iowa Administrative Code states that science instruction shall include conservation of natural resources; and environmental awareness.

The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.

Essential Concept and/or Skill: ***Understand and apply knowledge of the functions and interconnections of the major human body systems including the breakdown in structure or function that disease causes.***
The human organism has systems for digestion, respiration, reproduction, circulation, excretion, movement, control, and coordination, and for protection from disease. These systems interact with one another.

Disease is a breakdown in structures or functions of an organism. Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.

Essential Concept and/or Skill: ***Understand and apply knowledge of organisms and their environments, including:***

- ***Structures, characteristics, and adaptations of organisms that allow them to function and survive within their habitats.***
- ***How individual organisms are influenced by internal and external factors.***
- ***The relationships among living and non-living factors in terrestrial and aquatic ecosystems.***

Animals depend on plants. Some animals eat plants for food. Other animals eat animals that eat the plants.

An organism's patterns of behavior are related to the nature of that organism's environment, including the kinds and numbers of other organisms present, the availability of food and resources, and the physical characteristics of the environment. When the environment changes, some plants and animals survive and reproduce, others die or move to new locations.

All organisms cause changes in the environment in which they live. Some of these changes are detrimental to the organism or other organisms, whereas others are beneficial.

Illustration of ***Understand and apply knowledge of organisms and their environments, including:*** • ***Structures, characteristics, and adaptations of organisms that allow them to function and survive within their habitats.*** • ***How individual organisms are influenced by internal and external factors.*** • ***The relationships among living and non-living factors in terrestrial and aquatic ecosystems.*** in the ICLE's Rigor and Relevance Framework	
Quadrant C The teacher asks students to place bread, bran, potato and lettuce into various corners of a darkling beetle container and asks students to observe and record food preferences. They then make a claim about their results.	**Quadrant D** Students generate their own questions about mealworm behavior and design investigations that allow for data collection and analysis.
Quadrant A Students are given pictures of stages of butterfly and mealworm life cycles. They record/sketch observations of each stage and then compare the similarities and differences of the two creatures.	**Quadrant B** Students are given a mealworm to observe over a two week period. Students record their data and observations.

Essential Concept and/or Skill: ***Understand and apply knowledge of environmental stewardship.***
Chapter 12 of the Iowa Administrative Code states that science instruction shall include conservation of natural resources; and environmental awareness.

Humans change environments in ways that can be either beneficial or detrimental to themselves or other organisms.

Essential Concept and/or Skill: ***Understand and apply knowledge of basic human body systems and how they work together.***
The human organism has systems which interact with one another. These systems include circulatory, respiratory, digestive, musculoskeletal, etc.

Essential Concept and/or Skill: ***Understand and apply knowledge of personal health and wellness issues.***
See 21st Century Skills of the Iowa Core Curriculum.

Primary (K-2) Details and Example

Essential Concept and/or Skill: ***Understand and apply knowledge of the characteristics of living things and how living things are both similar to and different from each other and from non-living things.***
Living things share some common characteristics that are both similar to and different from non-living things.

Different species of plants and animals have different observable characteristics by which they can be classified.

Essential Concept and/or Skill: ***Understand and apply knowledge of life cycles of plants and animals.***
Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying.

Plants and animals closely resemble their parents.

Essential Concept and/or Skill: ***Understand and apply knowledge of the basic needs of plants and animals and how they interact with each other and their physical environment.***
Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light.

Organisms interact with each other and their physical environment.

Organisms can survive only in environments in which their needs can be met.

The world has many different environments, and distinct environments support the life of different types of organisms.

Illustration of ***Understand and apply knowledge of the basic needs of plants and animals and how they interact with each other and their physical environment.*** in the ICLE's Rigor and Relevance Framework	
Quadrant C The teacher will ask the class to help design experiments that will provide evidence of the conditions needed for optimal growth of bean seeds. They will grow bean seeds under different conditions, record their observations, and draw conclusions about needs for the bean plant.	**Quadrant D** Students plan, plant and tend a butterfly or hummingbird garden.
Quadrant A Using prior knowledge and information text, students and teacher will use a Venn diagram to compare and contrast the basic needs of plants and animals.	**Quadrant B** The teacher asks the class if they would like to have a classroom pet. Students form small groups to discuss responsibilities of taking care of a class pet. The whole class meets together to share ideas and form guidelines for the class to follow.

Essential Concept and/or Skill: ***Understand and apply knowledge of ways to help take care of the environment.***
Chapter 12 of the Iowa Administrative Code states that science instruction shall include conservation of natural resources; and environmental awareness.

Humans depend on their natural and constructed environments.

Humans change environments in ways that can be either beneficial or detrimental to themselves or other organisms.

Essential Concept and/or Skill: ***Understand and apply knowledge of basic human body structures (human body parts and their functions).***
Humans have distinct body structures for functions including but not limited to thinking, walking, holding, seeing and talking.

Essential Concept and/or Skill: ***Understand and apply knowledge of good health habits.***
See 21st Century Skills of the Iowa Core Curriculum.

Appendix

*Integrated Standards

Students should be proficient in understandings, abilities, and skills associated with the following integrated standards, including but not limited to, those listed below:

Science as Inquiry:
Identify questions and related concepts; design and conduct scientific investigations; use technology and mathematics; formulate and revise scientific explanations and models; recognize and analyze alternative explanations and models, communicate and defend a scientific argument, observe; experiment, measure, graph, evaluate, discuss/debate, research, collect/analyze data, imagine, diagram, concept map, engage in peer review, recognize experimental error, reflect, and predict.

Science and Technology:
Identify problem or design an opportunity; propose a design and choose between alternative solutions; implement proposed solution; evaluate solution and its consequences; communicate a problem, process, and solution; use computer software, device interfaces, lab equipment, calculators, and GPS; use presentation software and hardware, communications equipment, and remote sensing equipment; generate and manipulate data; describe the connection between technology and the state of current knowledge,

Science in Personal and Social Perspectives:
Make appropriate personal/lifestyle/technology choices, evaluate, observe, discuss/debate, recognize interactions and interdependencies at all levels, explain, describe environmental effects of public policy, choose appropriate course(s) of action.

History and Nature of Science:
Understand significance of historical scientific events and technological advances; recognize/relate contributions of other cultures, groups and individuals; work as part of a team; build on work of others; engage in peer review; use logical arguments; rely on evidence; recognize/use new information; change hypotheses; identify/evaluate “great leaps”; recognize/evaluate what is and is not science.