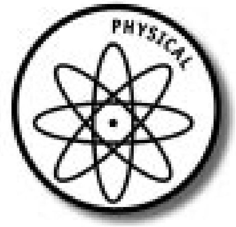
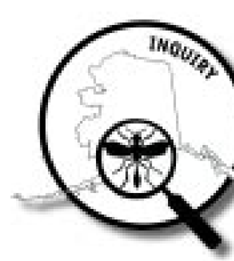
Translating Standards to Practice

A Teacher's Guide to Use and Assessment of the Alaska Science Standards

LEVEL 4, Ages 15–18





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A Teacher's Guide to Use and Assessment of the Alaska Science Standards

LEVEL 4

Developed collaboratively by the Alaska State Department of Education & Early Development and the Alaska Rural Systemic Initiative with funding provided by the National Science Foundation.

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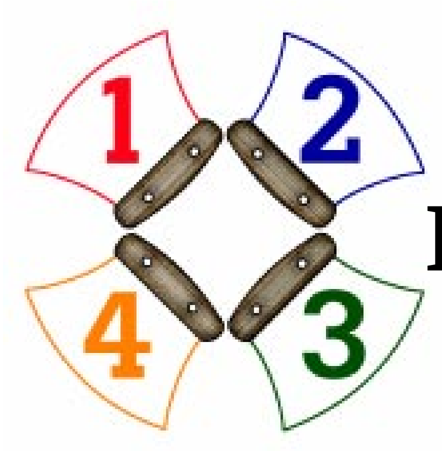

Introduction

Translating Standards to Practice: A Teacher's Guide to Assessment of the Alaska Science Standards were developed by Alaska educators and members of the business, native, and scientific communities to help promote scientific literacy and understanding for Alaska science students. As such, they were written to enhance, complement, and integrate the *Alaska Science Content Standards* and the *Alaska Standards for Culturally Responsive Schools* to further education in the sciences. These standards borrow heavily from the *National Science Education Standards* (NRC, 1995) as well as the *Benchmarks for Science Literacy* (AAAS, 1993) and are intended to help teachers provide students with an integrated and comprehensive understanding of science. Additionally, they were written to help enhance student understanding of Alaska culture, including the traditional and the scientific, and how they relate to one another. Teaching how the traditional and scientific relate to one another, through the use of *Translating Standards to Practice: A Teacher's Guide to Assessment of the Alaska Science Standards*, can provide an exciting and educational process that will invoke a sense of pride and self confidence in both students and teachers. The standards were developed collaboratively by the Alaska State Department of Education & Early Development and the Alaska Rural Systemic Initiative, with funding generously provided by the National Science Foundation.

Purpose

In 1994 the *Alaska Science Content Standards* were published with the goal of defining what students should know and be able to do in science by the time they complete their K–12 public education experience. These guidelines elaborate the expectations regarding student achievement and explain *how well* students should understand important scientific concepts and skills and how they relate to the environment around them. Corresponding assessments, supporting classroom ideas, and samples of student work were added to show how they might fit in a curriculum. These illustrate what *meeting the standard* may look like in the classroom. The sample assessments, which are in measurable terms, with a scoring guide, have been provided. The assessments can then be used to provide feedback to the students about how well they are meeting expectations. The assessments are also feedback to educators about how well their students are learning and how well they are meeting the *Alaska Science Content Standards*. It is important to note that these guidelines, assessments, and procedures were written illustratively—as ideas—not mandates. It should also be understood that this document is intended to help provide guidance to districts through the examples provided as they make choices regarding which standards to focus on at various benchmark age levels, as well as what *aspects* of the standards are focused on and when. The standards were written to reflect the diversity and richness of Alaska that makes teaching Alaskan students so exciting. Therefore, teachers may use them as guidelines for writing their own performance assessment activities or simply as examples to better understand particular aspects of the content standards at benchmark age levels. The standards were written to provide ideas relating to the wisdom of the cultural traditions of the Elders as well as the technological advances of the scientific community, bridging the gap between science and cultural practices to make learning more fun and appealing.

About This Document

This document presents an expanded view of the content standards for Alaska students. Performance standard statements have been written at each benchmark age level (5–7, 8–10, 11–14, 15–18). However, this document is really a "sampler" as examples of the expanded performance assessments, corresponding procedures, scoring guides, and in a very few cases, sample mini-units (elaborated classroom units), are provided for only a portion of the *Alaska Science Content Standards*—A, B, C, and D. The schematic shown below and "definitions" of the components of the document illustrate how the document is organized. The electronic version can be accessed via the Alaska Native Knowledge Network website at http://www.ankn.uaf.edu. Cross references to other pertinent Alaska standards, as well as to the National Research Council's *National Science Education Standards* and the American Association for the Advancement of Science's *Benchmarks for Science Literacy*, have been provided to show connections and further illuminate the intention of the *Alaska Science Content Standards*.

This document does **not** provide a list of mandated understandings and skills. The content standards provide a broad overview of essential learnings. The four domains described in the A, B, C, and D statements are elaborated by the key elements and describe what we agree are essential to the discipline and should be learned by all students in Alaska. The specific dimension of the content standards that should be taught and the performance to show mastery are the choice of the district, community, school, or classroom, not the document. This document is a guide for making the choice at the local level.

Definitions

Content Standard
What Alaskans want students to know and be able to do as a result of their public schooling.

Key Element
An important focus within a content standard.

Performance Standard
An example of how students at a specific age level demonstrate proficiency and understanding of a content standard focus (key element).

Sample Assessment Idea
A potential task designed to assess a student's proficiency and understanding of a performance standard.

Expanded Assessment Idea
A sample assessment idea elaborated to include procedure, reflection and revision, and level of performance.

Procedure
Step-by-step instructions to guide the implementation of an expanded assessment idea.

Reflection and Revision
A final step of procedure, which represents a collection of brief ideas or methods, intended to strengthen, clarify, and improve student understanding and proficiency.

Level of performance
A task-specific scoring guide used to assess how well students meet the performance standard.

Frequently Asked Questions

Why was *Translating Standards to Practice: A Teacher's Guide to Assessment of the Alaska Science Standards* document written?

It was prepared to:

- elaborate the Alaska Science Content Standards to more fully explain what students need to know and are able to do;
- help guide curriculum development in schools and districts;
- provide sample developmentally appropriate activities for each standard;
- provide educators with innovative performance assessment activities.

What are Performance Standards?

Performance standards define the nature of the evidence and quality to which a student understands the content standards.

What makes performance standards different from content standards?

The content standards are designed to broadly define what scientific concepts, skills, and applications are to be taught in Alaska's schools, whereas these guidelines are more detailed definitions of how well students need to know the science and what they ought to be able to do with that knowledge.

What are performance assessments?

Performance assessments help define how well students:

- understand science;
- show what they can do;
- relate science to society;
- communicate knowledge

by providing performance opportunities for students to demonstrate their understanding.

Why should I use performance activities with my students?

- To document student progress in meeting the Alaska Science Content Standards.
- To help students become accountable for their learning.
- To provide opportunities for students to learn by "doing."
- To give students a variety of opportunities to show that they can "meet" the content standards.

What if I can't use a particular performance assessment in my classroom?

The performance assessments were written as sample suggestions. You may use them as models for writing your own performance assessment activities.

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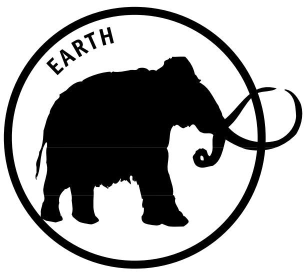

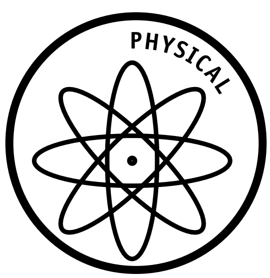

Alaska Science Content Standard A

Level 1, Ages 15–18

A student should understand scientific facts, concepts, principles, and theories.

Level 4

Alaska Science Key Element A1

A student who meets the content standard should understand models describing the nature of molecules, atoms, and sub-atomic particles and the relation of the models to the structure and behavior of matter.

Performance Standard Level 4, Ages 15–18

Students develop, create and use models to demonstrate their understanding of the nature of particles and their interactions on the molecular, atomic and subatomic levels, and how these explain the physical and chemical properties of matter.

Sample Assessment Ideas

- Students experiment with puffed rice and a Van DeGraaf static electricity generator OR an "electric ferry" apparatus (styrofoam, tin cans, pencil, string, tack, electron source); build models to explain the observations using subatomic, atomic, molecular, and particulate structures.
- Students compare the viscosity of different oils, greases, petroleum and synthetic lubricants at different temperatures; build models to explain differences in properties.

Expanded Sample Assessment Idea

- Students examine samples of salt (NaCl) crystals and sugar crystals; prepare solutions and measure conductivity and freezing points; build models that exhibit differences at the subatomic, atomic and molecular level of organization and account for the differences in observations. **[Proper SAFETY precautions should be used.]**

Procedure

Students will:

1. Use a magnifying glass or microscope and hardness test device (e.g. scratch block) to observe and describe properties of salt and sugar crystals.
2. Prepare quantitative solutions of at least two different concentrations of salt in water (e.g. 0.1g per 100g water, and 2 g per 100 g water) and attempt to do the same using hexane instead of water.
3. Prepare quantitative solutions of at least two different concentrations of sugar in water (e.g. 0.1g per 100g water, and 2 g per 100 g water) and attempt to do the same using hexane instead of water.
4. Observe and compare the properties of the solutions using simple conductivity apparatus.
5. Observe and compare the freezing point of each solution and the freezing point of pure water and pure hexane.
6. Build models to represent the two different solids and the different solutions; models should include differences at the subatomic level (i.e. electrons and nucleus), atomic level (i.e. ions vs. covalent bonds) and the molecular level (i.e. polar vs. non-polar solvents).
7. Use the models to explain orally (or in writing) the difference between a solid and a solution.

Reflection and Revision

Use the models to explain how differences between the solid and their solutions leads to the observed differences in properties. Why do some solids dissolve in some liquids and not in others?

Stage 4 Student work is complete, correct and shows evidence of logical reasoning and detailed evidence of extension and transfer of knowledge related to particle interactions. Models accurately represent both crystalline and solution structures in terms of the subatomic, atomic and molecular components. The models are used to explain most of the observed differences between ionic and covalent molecules (dissolving, solubility, conductivity, and changes in freezing points.)

Stage 3 Student work shows evidence of logical reasoning and some evidence of extension or transfer of knowledge related to particle interactions. Models represent crystalline and solution structure in terms of the subatomic, atomic and molecular components though minor errors or omissions may be present. The models are used to explain some of the observed differences between ionic and covalent molecules (dissolving, solubility, conductivity, or changes in freezing points.)

Stage 2 Student work may show evidence of skilled craftsmanship but shows limited evidence of knowledge related to particle interactions or subatomic, atomic, and molecular structures. Models represent crystalline or solution structures and are used to explain at least one of the observed differences between ionic and covalent molecules (dissolving, solubility, conductivity, or changes in freezing points.)

Stage 1 Student work is mostly incomplete, incorrect and shows little or no evidence of knowledge related to particle interactions.

Standards Cross-References

National Science Education Standards

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 atoms together. (Page 178)

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. (Page 178)

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. (Page 178)

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. (Page 178)

Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element. (Page 178)

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. (Page 178)

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. (Page 179)

The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them. (Page 179)

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. (Page 179)

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. (Page 179)

Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance. (Page 180)

Benchmarks

The usefulness of a model can be tested by comparing its predictions to actual observations in the real world. But a close match does not necessarily mean that the model is the only "true" model or the only one that would work. (Page 270)

A physical or mathematical model can be used to estimate the probability of real-world events. (Page 230)

Atoms are made of a positive nucleus surrounded by negative electrons. An atom's electron configuration, particularly the outermost electrons, determines how the atom can interact with other atoms. Atoms form bonds to other atoms by transferring or sharing electrons. (Page 80)

The nucleus, a tiny fraction of the volume of an atom, is composed of protons and neutrons, each almost two thousand times heavier than an electron. The number of positive protons in the nucleus determines what an atom's electron configuration can be and so defines the element. In a neutral atom, the number of electrons equals the number of protons. But an atom may acquire an unbalanced charge by gaining or losing electrons. (Page 80)

Neutrons have a mass that is nearly identical to that of protons, but neutrons have no electric charge. Although neutrons have little effect on how an atom interacts with others, they do affect the mass and stability of the nucleus. Isotopes of the same element have the same number of protons (and therefore electrons) but differ in the number of neutrons. (Page 80)

Scientists continue to investigate atoms and have discovered even smaller constituents of which electrons, neutrons, and protons are made. (Page 80)

When elements are listed in order by the masses of their atoms, the same sequence of properties appears over and over again in the list. (Page 80)

Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns. An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules. (Page 80)

The configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others. (Page 80)

Level 4

Alaska Science Key Element A2

A student who meets the content standard should understand the physical, chemical, and nuclear changes and interactions that result in observable changes in the properties of matter (Changes and Interactions of Matter).

Performance Standard Level 4, Ages 15–18

Students describe and explain a common chemical reaction including atomic structure, chemical bonding and reaction rates.

Sample Assessment Ideas

- Students burn (or attempt to burn) four different substances; make qualitative and quantitative evaluations before and after combustion; state what has happened in each combustion attempt.
- Students use metals and non-metals in a reaction with hydrochloric acid; make qualitative and quantitative evaluations before and after the reactions; use chemical symbols and models to describe each chemical reaction.

Expanded Sample Assessment Idea

- Students build a bottle “firework” using hydrochloric acid and calcium carbonate; explain the complete reaction; relate the chemical reaction to the production of cave formations. **[Proper SAFETY should be used.]**

Materials

- ✔ 1 or 2 liter plastic bottle
- ✔ rubber stopper to fit
- ✔ streamers to tape to stopper
- ✔ calcium carbonate
- ✔ hydrochloric acid OR vinegar (vinegar can be used but it gives the students a more difficult equation)
- ✔ balance
- ✔ graduated cylinder
- ✔ paper towels

Procedure

Students will:

1. Measure a given mass (about 1 gram) of calcium carbonate; place in a paper twist.
2. Measure 5–10 mL of 0.1M hydrochloric acid into a bottle.
3. Place the paper twist of carbonate in the bottle and rapidly cork the bottle.
4. Shake to mix the chemicals; **DO NOT POINT** at anyone.
5. Make complete lab records in a journal about what was observed and what happens.
6. Write equations to explain what is observed.

Reflection and Revision

How does this activity relate to the formation of stalactites and stalagmites in caves? To the weathering of marble statues in industrial cities? Instead of popping the cork, design a way to test the gas that is produced and prove its identity; get approval of the design; carry out the tests; interpret the results in a journal.

Levels of Performance

Stage 4 — Student work shows clear understanding of matter rearrangements that take place in chemical reactions. Balanced equations are written for all reactions. Observations are thorough and interpreted in considerable detail using logical reasoning.

Stage 3 Student work shows understanding of matter rearrangements that take place in chemical reactions. Balanced equations are written for most reactions. Observations are thorough and interpreted with some evidence of logical reasoning although minor errors may be present.

Stage 2 Student work shows limited understanding of matter rearrangements that take place in chemical reactions. Equations are attempted but they are not balanced or they contain errors. Observations are minimal, contain errors or are interpreted with limited evidence of logical reasoning.

Stage 1 Student work shows little understanding of matter rearrangements that take place in chemical reactions. Equations, if present, are highly flawed. Observations are minimal or totally incorrect, and observations, if present, contain major misconceptions.

Standards Cross-References

National Science Education Standards

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. (Page 178)

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Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element. (Page 178)

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. (Page 179)

The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them. (Page 179)

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. (Page 179)

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. (Page 179)

Chemical reactions may release or consume energy. Some reactions such as the burning 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. (Page 179)

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. (Page 179)

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, on the temperature, and on the properties—including shape—of the reacting species. (Page 179)

Catalysts, such as metal surfaces, accelerate chemical reactions. Chemical reactions in living systems are catalyzed by protein molecules called enzymes. (Page 179)

Benchmarks

The nucleus of radioactive isotopes is unstable and spontaneously decays, emitting particles and/or wavelike radiation. It cannot be predicted exactly when, if ever, an unstable nucleus will decay, but a large group of identical nuclei decay at a predictable rate. This predictability of decay rate allows radioactivity to be used for estimating the age of materials that contain radioactive substances. (Page 80)

Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns. An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules. (Page 80)

The configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others. (Page 80)

The rate of reactions among atoms and molecules depends on how often they encounter one another, which is affected by the concentration, pressure, and temperature of the reacting materials. Some atoms and molecules are highly effective in encouraging the interaction of others. (Page 80)

Alaska Science Key Element A3

A student who meets the content standard should understand models describing the composition, age, and size of our universe, galaxy, and solar system and understand that the universe is constantly moving and changing (Universe).

Performance Standard Level 4, Ages 15–18

Students use secondary research to develop models that explain the origin and continued development of the solar system, galaxy, and the universe.

Sample Assessment Ideas

- Students make a model of the sun-Earth-lunar system that is accurately scaled for both size and distance.
- Students conceptually demonstrate the "Big Bang", including the center of expansion and continued thinning of mass per volume by inflating a balloon covered with dots from a marking pen.

Expanded Sample Assessment Ideas

- Students model star movement and explain the red shift.

Procedure

Students will:

1. Break into groups of four, each contributing specific information to the activity.
2. Use the Internet to collect information about star movement.
3. Demonstrate the Doppler effect by moving a sound source of constant pitch towards the listener and away from the listener.
4. Discuss how to use the Doppler effect to describe the relative motion of stars.
5. Make a model or draw a picture and use it to demonstrate how a change in motion and position causes a change in wave frequency.
6. Discuss the red-shift of light.

Reflection and Revision

Compare and contrast light energy and sound energy. What other energy sources are emitted from stars in addition to light energy? How is the energy source used to identify the type of star? The distance of the star? What evidence is used to identify the chemical composition of a star? What evidence is used to identify the age of a galaxy? Use your model to explain the motion and movement of blue-shifted stars and galaxies.

Level of Performance

Stage 4 — Student explanation is complete and shows evidence of logical reasoning. The model or drawing accurately describes how a change in motion and position causes a change in wave frequency. The student uses the model or drawing to explain blue-shift and the movement of blue-shifted galaxies. The student explanation contains detailed evidence of how energy-related information is used to classify, identify, and describe stars or galaxies in the universe.

Stage 3 — Student explanation shows evidence of clear and logical reasoning, but may contain minor errors or omissions. The model or drawing describes how a change in motion and position causes a change in wave frequency. Minor errors or omissions may be present. The student uses the model or drawing to explain blue-shift or the movement of blue-shifted galaxies. The student explanation contains some evidence of how energy-related information is used to classify, identify, or describe stars or galaxies in the universe.

Stage 2 The model or drawing may contain evidence of skilled craftsmanship but may be incomplete, incorrect, or lack detail. Student explanation contains limited knowledge of how to classify, identify, or describe stars or galaxies in the universe. It may contain errors of science fact and reasoning.

Stage 1 The model, drawing, and student explanation are largely incomplete and incorrect.

Standards Cross-References

National Science Education Standards

The sun, the Earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early Earth was very different from the planet we live on today. (Page 189)

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. (Page 190)

Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by 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. (Page 190)

Benchmarks

The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements that are found on the Earth and to behave according to the same physical principles. Unlike the sun, most stars are in systems of two or more stars orbiting around one another. (Page 65)

On the basis of scientific evidence, the universe is estimated to be over ten billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years. Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense. The process of star formation and destruction continues. (Page 65)

Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. (Page 65)

Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe. (Page 65)

Alaska Science Key Element A4

A student who meets the content standard should understand observable natural events such as tides, weather, seasons, and moon phases in terms of the structure and motion of the Earth (Earth).

Performance Standard Level 4, Ages 15–18

Students explain tides, weather, seasons, and phases of the moon including the appropriate concepts of gravity, the Coriolis effect, role of the atmosphere, and Earth's rotation and revolution.

Sample Assessment Ideas

- Students research how air and water regions of different temperature and density move to drive circulation patterns and large-scale weather patterns.
- Students debate the scientific evidence for and against global warming.

Standards Cross-References

National Science Education Standards

Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. (Page 189)

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. (Page 189)

Benchmarks

Life is adapted to conditions on the Earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of radiation from the sun that allows water to cycle between liquid and vapor. (Page 70)

Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall and such circulation, influenced by the rotation of the Earth, produces winds and ocean currents. (Page 70)

Level 4

Alaska Science Key Element A5

A student who meets the content standard should understand the strength and effects of the forces of nature, including gravity and electromagnetic radiation (Forces of Nature).

Performance Standard Level 4, Ages 15–18

Students explain how gravity and electromagnetic forces operate according to simple principles and how they can be used in applications such as mineral resource prospecting, satellites, space travel and to affect natural phenomena such as the aurora.

Sample Assessment Ideas

- Students explain how microwaves, radio waves, and x-rays are related and identify technologies which utilize them in everyday applications.
- Students use observations on the Internet or collect data related to sunspot activity, the occurrence of electromagnetic disturbances on Earth, aurora displays, NASA precautionary plans, and communications blackouts; create a report that explains how electromagnetism affects life on Earth.

Standards Cross-References

National Science Education Standards

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 inversely proportional to the square of the distance between them. (Page 180)

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. (Page 180)

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. (Page 180)

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 to understand electric motors and generators. (Page 180)

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. (Page 180)

In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behavior. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons. (Page 181)

Benchmarks

Accelerating electric charges produce electromagnetic waves around them. A great variety of radiations are electromagnetic waves, radio waves, microwaves, radiant heat, visible light, ultraviolet radiation, x-rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma waves, the shortest. In empty space, all electromagnetic waves move at the same speed—the “speed of light.” (Page 92)

Gravitational force is an attraction between masses. The strength of the force is proportional to the masses and weakens rapidly with increasing distance between them. (Page 96)

Electromagnetic forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. At the atomic level, electric forces between oppositely charged electrons and protons hold atoms and molecules together and thus are involved in all chemical reactions. On a larger scale, these forces hold solid and liquid materials together and act between objects when they are in contact—as in sticking or sliding friction. (Page 96)

There are two kinds or charges—positive and negative. Like charges repel one another, opposite charges attract. In materials, there are almost exactly equal proportions of positive and negative charges, making the materials as a whole electrically neutral. Negative charges, being associated with electrons, are far more mobile in materials than positive charges are. A very small excess of negative charges in a material produces noticeable electric forces. (Page 96)

Different kinds of materials respond differently to electric forces. In conducting materials such as metals, electric charges flow easily, whereas in insulating materials such as glass, they can move hardly at all. At very low temperatures, some materials become superconductors and offer no resistance to the flow of current. In between these extremes, semiconducting materials differ greatly in how well they conduct, depending on their exact composition. (Page 97)

Magnetic forces are very closely related to electric forces and can be thought of as different aspects of a single electromagnetic force. Moving electric charges produce magnetic forces and moving magnets produce electric forces. The interplay of electric and magnetic forces is the basis for electric motors, generators, and many other modern technologies, including the production of electromagnetic waves. (Page 97)

The forces that hold the nucleus of an atom together are much stronger than the electromagnetic force. That is why such great amounts of energy are released from the nuclear reactions in the sun and other stars. (Page 97)

Level 4

Alaska Science Key Element A6

A student who meets the content standard should understand that forces of nature cause different types of motion, and describe the relationship between these forces and motion (Motion).

Performance Standard Level 4, Ages 15–18

Students explain common examples of linear and rotational motion using Newton's Laws of Motion.

Sample Assessment Ideas

- Students calculate speed and position as a function of time for a boat traveling both upstream and downstream in a known current if the motor force of the boat is known.
- Students describe and calculate the orbital velocity of a geostationary satellite at a fixed height above Earth.

Expanded Sample Assessment Idea

- Students experiment with sleds to determine acceleration due to a constant force.

Procedure

Students will:

1. Mark off 5m increments along a track; use a spring scale between the sled and a pulling force to assure constant force; tow a sled or skateboard on a hard or ice surface (e.g. lake, well-packed snow machine track, ice rink.)
2. Measure time between marks.
3. Calculate velocity.
4. Graph velocity vs. time and determine acceleration; graph acceleration vs. time.
5. Vary the weight on the slide, surface type, force; repeat calculations and graphing steps.

Reflection and Revision

Write a formal lab report that includes:

- ✔ **Materials & Methods** (include calculations and graphs)
- ✔ **Data Analysis** (include sources of experimental error due to the sled, the snow type, human error; methods to reduce experimental error; description of the forces acting on the sled when it is stationary, when it is moving)
- ✔ **Data Interpretation** (include a description of the experimental results using Newton's Laws of Motion and coefficient of friction)
- ✔ **Applications** (include a discussion of Newton's three laws at work in a related local activity such as driving a vehicle, playing sports, hunting, and so on)

Levels of Performance

Stage 4 Student work is complete, correct and shows detailed evidence of the transfer and extension of knowledge that relates forces to motion. Each section of the lab report is detailed and shows evidence of logical reasoning. Calculations are accurate; graphs are correctly labeled and accurately represent the observations; error analysis contains detailed discussion of each source of error; experimental results are interpreted according to Newton's Laws of Motion as well as coefficient of friction and the Applications section includes a thorough discussion of how Newton's Laws of Motion apply to daily living or a local activity.

Stage 3 — Student work is mostly complete and shows evidence of the transfer or extension of knowledge that relates forces and motion. Most sections of the lab report shows evidence of logical reasoning, although some sections may contain minor errors or omissions. Calculations are mostly accurate; graphs are labeled and represent the observations; error analysis contains a discussion of sources of error; experimental results are interpreted according to Newton's Laws of Motion or coefficient of friction; and the applications section includes a discussion of how Newton's Laws of Motion apply to daily living or local activity

Stage 2 — Student work may be incomplete and shows limited evidence of knowledge of forces or motion. The lab report may include a preliminary or first draft attempt on the required sections though it contains errors of science fact and reasoning.

Stage 1 — Student work is mostly incomplete and shows misconceptions relating forces and motion.

Standards Cross-References

National Science Education Standards

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. (Page 179)

Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter. (Page 180)

Benchmarks

The change in motion of an object is proportional to the applied force and inversely proportional to the mass. (Page 91)

All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion. (Page 91)

Accelerating electric charges produce electromagnetic waves around them. A great variety of radiations are electromagnetic waves: radio waves, microwaves, radiant heat, visible light, ultraviolet radiation, x rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed—the "speed of light." (Page 92)

Whenever one thing exerts a force on another, an equal amount of force is exerted back on it. (Page 92)

The observed wavelength of a wave depends upon the relative motion of the source and the observer. If either is moving toward the other, the observed wavelength is shorter; if either is moving away, the wavelength is longer. Because the light seen from almost all distant galaxies has longer wavelengths than comparable light here on Earth, astronomers believe that the whole universe is expanding. (Page 92)

Waves can superpose on one another, bend around corners, reflect off surfaces, be absorbed by materials they enter, and change direction when entering a new material. All these effects vary with wavelength. The energy of waves (like any form of energy) can be changed into other forms of energy. (Page 92)

Level 4

Alaska Science Key Element A7

A student who meets the content standard should understand how the Earth changes because of plate tectonics, earthquakes, volcanoes, erosion and deposition, and living things (Processes that Shape the Earth).

Performance Standard Level 4, Ages 15–18

Students explain short-term and long-term transformations of the Earth's surface, including those caused by living things and human intervention.

Sample Assessment Ideas

- Students take a field trip to a river bank, ocean beach, or other area affected by a recent storm; observe, examine and record the damage of a storm; discuss changes to habitats; discuss how changes in plant, animal, and human activity in the area increased or decreased these changes.
- Students investigate the effects of an oil spill; predict long-term environmental changes.

Standards Cross-References

National Science Education Standards

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. (Page 189)

The outward transfer of Earth's internal heat drives convection circulation in the mantle which propels the plates comprising Earth's surface across the face of the globe. (Page 189)

Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents. (Page 189)

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. (Page 189)

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. (Page 189)

Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods includes using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed. (Page 189)

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. (Page 189)

Benchmarks

The formation, weathering, sedimentation, and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same as its forms change. (Page 74)

The slow movement of material within the Earth results from heat flowing out from the deep interior and the action of gravitational forces on regions of different density. (Page 74)

The solid crust of the Earth—including both the continents and the ocean basins—consist of separate plate that ride on a denser, hot, gradually deformable layer of the Earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Ocean floor plates may slide under continental plates, sinking deep into the Earth. The surface layers of these plates may fold, forming mountain ranges. (Page 74)

Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands. (Page 74)

Level 4

Alaska Science Key Element A8a

A student who meets the content standard should understand the scientific principles and models that describe the nature of physical, chemical, and nuclear reactions (Energy Transformations).

Performance Standard Level 4, Ages 15–18

Students explain how the absorption or emission of energy is related to physical, chemical, and nuclear reactions and explains how these reactions can be quantitatively accounted for in terms of changes in arrangements of neutrons, protons, electrons, atoms or molecules.

Sample Assessment Ideas

- Students perform flame tests on Li, Na, Ba, and Cu salts; explain the observations in terms of photon emissions and energetics.
- Students write balanced equations to account for the rearrangement of atoms in chemical reactions. (NOTE: teacher provides lists of reactants and products.)
- Students write balanced equations to account for the rearrangement of neutrons, protons, and electrons in nuclear reactions such as radioactive decay, uranium fission, and hydrogen or helium fusion. (NOTE: teacher provides lists of reactants and products.)

Expanded Sample Assessment Idea

- Students perform a standard calorimetry experiment to show that the energy release when an acid is mixed with a base depends on the exact amounts of acid and base reacted.

Materials

- ✔ solutions of 1M HCl and 1M NaOH
- ✔ styrofoam cup, a covering for the top (“take-out” coffee cups with lids)
- ✔ thermometer
- ✔ stirrer (plastic)
- ✔ graduated cylinders or burettes

Procedure

NOTE: Proper safety procedures must be followed!

Students will:

1. Measure amounts of acid and base solutions (different students in class use different amounts).
2. Measure temperature of both solutions—equilibrate at room temperature)
3. Rapidly pour both solutions into cup; attach cup covering; insert thermometer into opening in cup covering; measure temperature as a function of time; record and plot data.
4. Compare results with other students in class who used different amounts of solutions.

Reflection and Revision

What data should be used to compare temperatures in different experiments? How reproducible is this experiment? How could the experiment be changed to reduce the variability? What is the pattern between volumes of solution used and highest temperature reached? How can the experiment be changed to standardize this data? Write the chemical equation for this reaction. What does the data tell about the reaction between and acid and a base?

Levels of Performance

Stage 4 — Student work is complete, correct and shows detailed evidence of understanding the distinction between temperature, heat and the measurement of heat emitted from a chemical reaction. Measurements and observations are detailed and interpreted with logical reasoning. Discussion indicates understanding of the principle that the energy emitted in a chemical reaction is proportional to amount of reaction occurring and the need to establish correct ratios based on volumes and concentrations of the reactants.

Stage 3 — Student work is mostly complete and shows some evidence of understanding the distinction between temperature, heat and the measurement of heat emitted from a chemical reaction. Measurements and observations are interpreted with logical reasoning. Discussion indicates understanding of the principle that energy emitted in a chemical reaction is proportional to the amount of reaction occurring.

Stage 2 — Student work may be incomplete and shows limited understanding of distinction between temperature, heat or the measurement of heat emitted from a chemical reaction. Measurements and observations lack detail and the interpretation and discussion may show errors of reasoning.

Stage 1 — Student work is mostly incomplete and contains misconceptions relating to temperature, heat and the measurement of heat emitted from a chemical reaction. Measurements, observations, interpretations and discussion, if present, are minimal, and show a lack of scientific reasoning.

Standards Cross-Referenced

National Science Education Standards

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. (Page 178)

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. (Page 178)

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. (Page 179)

Chemical reactions may release or consume energy. Some reactions such as the burning 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. (Page 179)

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. (Page 179)

Chemical reactions can take place in time periods ranging from the few femptoseconds (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, on the temperature, and on the properties—including shape—of the reacting species. (Page 179)

Catalysts, such as metal surfaces, accelerate chemical reactions. Chemical reactions in living systems are catalyzed by protein molecules called enzymes. (Page 179)

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. (Page 180)

Benchmarks

Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns. An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules. (Page 80)

The configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others. (Page 80)

The rate of reactions among atoms and molecules depends on how often they encounter one another, which is affected by the concentration, pressure, and temperature of the reacting materials. Some atoms and molecules are highly effective in encouraging the interaction of others. (Page 80)

Different energy levels are associated with different configurations of atoms and molecules. Some changes of configuration require an input of energy whereas others release energy. (Page 86)

When energy of an isolated atom or molecule changes, it does so in a definite jump from one value to another, with no possible values in between. The change in energy occurs when radiation is absorbed or emitted, so the radiation also has distinct energy values. As a result, the light emitted or absorbed by separate atoms or molecules (as in gas) can be used to identify what the substance is. (Page 86)

Energy is released whenever the nuclei of very heavy atoms, such as uranium or plutonium, split into middle weight ones, or when very light nuclei, such as those of hydrogen and helium, combine into heavier ones. The energy released in each nuclear reaction is very much greater than the energy given off in each chemical reaction. (Page 86)

Level 4

Alaska Science Key Element A8b

A student who meets the content standard should understand the scientific principles and models that state whenever energy is reduced in one place, it is increased somewhere else by the same amount (Energy Transformations).

Performance Standard Level 4, Ages 15–18

Students measure energy transfers that take place around them and use the data to examine The Law of Conservation of Energy.

Sample Assessment Ideas

- Students burn a candle or kerosene and measure the energy transferred to a measured amount of water; describe the relationship between energy in water and the fuel burned; identify all energy losses that occur.
- Students draw a diagram describing how photosynthesis in plants stores energy from the sun in the chemical bonds of sugars; identify energy losses to the environment.

Expanded Sample Assessment Idea

- Students trace the flow of energy from a food source to its final form; make calorimetry measurements to support these ideas.

Procedure

Students will:

1. Choose 3 foods from their daily diet that they will use in calorimetry experiments (at least one food item should be an oily, fatty food.)
2. Research the calorie content of the foods.
3. Perform standard calorimetry experiments burning a measured amount of one food to heat a measured amount of water.
4. Complete the calculations to determine energy content of food; identify corrections for energy losses.
5. Create a poster or model that traces energy inputs beginning with solar energy source, and showing all energy conservations.

Reflection and Revision

Create poster or model to display energy information. Include an error analysis—what are the sources of error? How can the experimental design be modified to significantly reduce the energy loss?

Levels of Performance

Stage 4 Student work is complete, correct, and shows detailed evidence of knowledge related to food energy, energy transfer and the Law of Conservation of Energy. Poster or model includes three foods, their calorie content; data and calculations using appropriate units from calorimetry experiment, and a detailed error analysis that includes modification to experimental design.

Stage 3 Student work is mostly complete, correct, and shows evidence of knowledge related to food energy and energy transfers, but may contain minor errors or omissions. Poster or model includes three foods, their calorie content; data and calculations from calorimetry experiment that may be represented without appropriate units, and a discussion of experimental error and how to reduce experimental errors.

Stage 2 — Student work may be incomplete and show limited evidence of knowledge related to food energy or energy transfers. Poster or model may show evidence of skilled craftsmanship but contain limited information related to food types, calorie content, and the calorimetry experiment.

Stage 1 — Student work is mostly incomplete, incorrect, shows evidence of major misconceptions relating to energy and energy transfers.

Standards Cross-References

National Science Education Standards

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. (Page 180)

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. (Page 180)

Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter. (Page 180)

Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance. (Page 180)

Benchmarks

Whenever the amount of energy in one place or form diminishes, the amount in other places or forms increases by the same amount. (Page 86)

Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much total energy remains, its being spread out more evenly means less can be done with it. (Page 86)

Level 4

Alaska Science Key Element A8c

A student who meets the content standard should understand the scientific principles and models that state that whenever there is a transformation of energy, some energy is spent in ways that make it unavailable for use (Energy Transformations).

Performance Standard Level 4, Ages 15–18

Students explain entropy and its affect on energy availability.

Sample Assessment Ideas

- “It is easier to mess things up than to put them in order.” This is often used as a way to show the idea of entropy as something happening in all the environment. Choose three examples from your home or community that seem to demonstrate this quote and explain why they do so.
- Students draw posters or diagrams and use them to explain all the energy and entropy changes happening in a snowmobile, including within the engine, and why all the energy from burning the fuel in the engine doesn’t go into driving the snowmobile forward. What is becoming less ordered as the snowmobile operates?

Expanded Sample Assessment Idea

- Students observe the following changes themselves or as demonstrations, and explain why they happen with special reference to energy and entropy changes.

Procedure

Students will:

1. Observe systems before and after a change has occurred. Suggested systems include:
   - Leave a saturated sugar solution on the window ledge; sugar crystals appear in a while
   - Stir solid ammonium thiocyanate crystals with barium hydroxide crystals
   - Hit a small rubber ball many times against a wall causes the ball to heat up.
   - Mix ammonium sulfate crystals and water.
   - Activate a drug store or athletic department “cold pack” or “hot pack”.
2. Carefully record observations.
3. Measure heat effects using a thermometer (before and after); record and tabulate results.
4. Build models to demonstrate what happens in the change.
5. Use the model as part of an oral presentation on what happens.

Reflection and Revision

Find one clear example of a similar change that demonstrates an entropy effect in the community/environment and create a poster to explain this to a parent group.

Levels of Performance

Stage 4 — Student work is complete, and shows clear understanding of kinetic and positional energy (entropy) and how these relate to processes and change. Measurements, data, observations, and inferences are detailed and accurate. An accurate model and poster are created, and used to effectively explain energy and entropy interactions.

Stage 3 — Student work is mostly complete, and shows understanding of kinetic and positional energy (entropy) and how these relate to processes and change. Measurements, data, observations, and inferences are appropriate, although they may contain minor errors or omissions. A reasonable model and poster are created, and used to describe energy and entropy interactions.

Stage 2 Student work may be incomplete, and shows limited understanding of kinetic or positional energy (entropy) or how they relate to processes and change. Measurements, data, observations, and inferences are incomplete, incorrect or lack detail and logical reasoning. Model and poster may show evidence of skilled craftsmanship but cannot be used to describe energy interactions.

Stage 1 Student work is mostly incomplete, and shows little or no understanding of energy or entropy. Data and observations are incomplete or incorrectly recorded. Model and poster may show evidence of skilled craftsmanship but are inaccurate and do not support explanations.

Standards Cross-References

National Science Education Standards

Heat consists of random motion and the vibrations of atoms, molecules, and ions. The higher the temperature, the greater the atomic or molecular motion. (Page 180)

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. (Page 180)

Everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly. Examples are the transfer of energy from hotter to cooler objects by conduction, radiation, or convection and the warming of our surroundings when we burn fuels. (Page 180)

Benchmarks

Heat energy in a material consists of the disordered motions of its atoms or molecules. In any interactions of atoms or molecules, the statistical odds are that they will end up with less order than they began—that is, with the heat energy spread out more evenly. With large numbers of atoms and molecules, the greater disorder is almost certain. (Page 86)

Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much total energy remains, its being spread out more evenly means less can be done with it. (Page 86)

Level 4

Alaska Science Key Element A9

A student who meets the content standard should understand the transfers and transformations of matter and energy that link living things and their physical environment from molecules to ecosystems (Flow of Matter and Energy).

Performance Standard Level 4, Ages 15–18

Students describe the relationship between energy and matter in a biological system.

Sample Assessment Ideas

- Students use different colored lights to grow elodea; count bubbles; draw conclusions.
- Students create a poster that compares the calorie content of equal masses of protein, carbohydrate, and lipid; discuss efficient energy storage mechanisms in a variety of plant and animal organisms.
- Students explain biomass conversions that take place in a simple food chain. (For example, sunlight to plants, plants to mice, mice to snakes.)

Standards Cross-References

National Science Education Standards

Plant cells contain chloroplasts, the site 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. This process of photosynthesis provides a vital connection between the sun and the energy needs of living systems. (Page 184)

The atoms and molecules on Earth cycle among the living and non-living components of the biosphere. (Page 186)

Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers. (Page 186)

All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations. With death, and the cessation of energy input, living systems rapidly disintegrate. (Page 186)

The energy for life primarily derives from the sun. 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 with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes. (Page 186)

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 usually store this energy temporarily in phosphate bonds of a small high-energy compound called ATP. (Page 186)

The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy, and by the ability of the ecosystem to recycle materials. (Page 186)

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. (Page 186)

Benchmarks

At times, environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. By burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide. (Page 121)

The amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials. Human activities and technology can change the flow and reduce the fertility of the land. (Page 121)

The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going. (Page 121)

Alaska Science Key Element A10

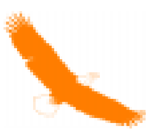
A student who meets the content standard should understand that living things are made up mostly of cells and that all life processes occur in cells (Cells).

Performance Standard Level 4, Ages 15–18

Students identify structure-function relationships at the subcellular, cellular, tissue, organ, and organism levels of organization.

Sample Assessment Ideas

- Students correctly identify basic cell organelles using samples of prepared cells from plants and animals; describe the function of basic cell organelles.
- Students research protective responses that plants display against herbivores; examine the physical and chemical properties of these defensive adaptations.



Expanded Sample Assessment Idea

- Students dissect a plant that grows and survives in the northern Alaska environment; identify environmental adaptations at the organism, tissue, and cellular level.

Procedure

Students will:

1. Draw the original plant including an image made from examination with a magnifying lens; label all structures and the epidermal covering of the plant, including the covering of stems, roots, and leaves.
2. Prepare samples for microscopic observation; view under low and high power magnification; draw and label.
3. Collect information about the shape and function of specialized cells, tissues, and organs needed to endure cold temperatures, high winds, frozen and scarce water.
4. Discuss cellular adaptations to environmental conditions (e.g. how cells of a tropical plant differ from an arctic plant.)

Reflection and Revision

What other location would require such plant adaptations?

Level of Performance

Stage 4 — Student work clearly and accurately explains how cell, tissue, and organ level adaptations help an organism survive in its environment. The structure-function relationship of specialized cells, tissues, and organs are each described in detail.

Stage 3 — Student work accurately explains how cell, tissue, and organ level adaptations help an organism survive in is environment. Some structure-function relationships of specialized cells, tissues, and organs are described.

Stage 2 — Student work attempts to describe cells, tissues, or organs in one or more organisms but descriptions of structure-function relationships are incomplete, incorrect, and may contain errors of science fact and reasoning.

Stage 1 — Student work is largely incomplete, incorrect, and contain errors of science fact and reasoning.

Standards Cross-References

National Science Education Standards

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 that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material. (Page 184)

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 a large set of protein catalysts, called enzymes. The breakdown of some of the food molecules enables the cell to store energy in specific chemicals that are used to carry out the many functions of the cell. (Page 184)

Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires. (Page 184)

Cell functions are regulated. Regulation occurs both through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division. (Page 184)

Plant cells contain chloroplasts, the site 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. This process of photosynthesis provides a vital connection between the sun and the energy needs of living systems. (Page 184)

Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues, and organs that comprise the final organism. This differentiation is regulated through the expression of different genes. (Page 184)

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. (Page 187)

Benchmarks

Every cell is covered by a membrane that controls what can enter and leave the cell. In all but quite primitive cells, a complex network of proteins provides organization and shape and, for animal cells, movement. (Page 113)

Within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback, and even movement. In addition to these basic cellular functions common to all cells, most cells in multicellular organisms perform some special functions that others do not. (Page 113)

The work of the cell is carried out by the many different types of molecules it assembles, mostly proteins. Protein molecules are long, usually folded chains made from 20 different kinds of amino-acid molecules. The function of each protein molecule depends on its specific sequence of amino acids and the shape the chain takes is a consequence of attractions between the chain's parts. (Page 114)

The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. The code used is virtually the same for all life forms. Before a cell divides, the instructions are duplicated so that each of the two new cells gets all the necessary information for carrying on. (Page 114)

Complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Cell behavior can also be affected by molecules from other parts of the organism or even other organisms. (Page 114)

Gene mutation in a cell can result in uncontrolled cell division called cancer. Exposure of cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer. (Page 114)

Most cells function best within a narrow range of temperature and acidity. At very low temperatures, reaction rates are too slow. High temperatures and/or extremes of acidity can irreversibly change the structure of most protein molecules. Even small changes in acidity can alter the molecules and how they interact. Both single cells and multicellular organisms have molecules that help to keep the cell's acidity within a narrow range. (Page 114)

A living cell is composed of a small number of chemical elements, mainly carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. Carbon atoms can easily bond to several other carbon atoms in chains and rings to form large and complex molecules. (Page 114)

Level 4

Alaska Science Key Element A11

A student who meets the content standard should understand that similar features are passed on by genes through reproduction (Heredity).

Performance Standard Level 4, Ages 15–18

Students build a model to show how the structure of DNA affects the structure of proteins, cells, and ultimately phenotypic characteristics of the organism.

Sample Assessment Ideas

- Students research and discuss the process of gene splicing beginning with the initial steps of gene identification; use this research to debate the ethics of whether or not human genes should be spliced into species of plants and animals.
- Students describe the difference between the DNA of a large local animal and the DNA of a mosquito.

Standards Cross-References

National Science Education Standards

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). Each DNA molecule in a cell forms a single chromosome. (Page 185)

Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome-and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next. (Page 185)

Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism's offspring. (Page 185)

Benchmarks

Some new gene combinations make little difference, some can produce organisms with new and perhaps enhanced capabilities, and some can be deleterious. (Page 108)

The sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents. (Page 108)

The information passed from parents to offspring is coded in DNA molecules. (Page 108)

Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment. (Page 109)

Gene mutations can be caused by such things as radiation and chemicals. When they occur in sex cells, the mutations can be passed on to offspring; if they occur in other cells, they can be passed on to descendant cells only. The experiences an organism has during its lifetime can affect its offspring only if the genes in its own sex cells are changed by the experience. (Page 109)

The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. Different parts of the instructions are used in different types of cells, influenced by the cell's environment and past history. (Page 109)

Level 4

Alaska Science Key Element A12

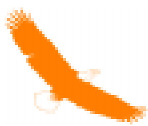
A student who meets the content standard should distinguish the patterns of similarity and differences in the living world in order to understand the diversity of life and understand the theories that describe the importance of diversity for species and ecosystems (Diversity).

Performance Standard Level 3, Ages 11–14

Students describe how diversity and genetic variability influence a species' survival rate under changing environmental conditions.

Sample Assessment Ideas

- Students closely study the features of at least five samples of a local species harvested in season (for example, five seals); identify similarities and differences.
- Students explain why diversity is important for the health of ecosystems.



Expanded Sample Assessment Idea

- Students compare algae and land plants; identify divergence as well as similarity; discuss the effect that adaptation has had on plant diversification and survival.

Procedure

Students will:

1. Investigate energy production in algae and land plants.
2. Use microscopes to compare the structures of both plants; draw and label diagrams of the structures, and identify the location of energy production.
3. Classify algae and land plants according to their structures and energy production.
4. Identify environmental needs of algae and plants including different structures and energy production.
5. Make an oral presentation to the class.
6. As a group, discuss various algae species including classification, cellular- and structural-adaptations; discuss various land plant species including classification (monocot vs. dicot, gymnosperm vs. angiosperm), cellular and structural-adaptations; discuss energy harnessing in algae vs. land plants.

Reflection and Revision

What specific structures must be observed to study energy productions? Describe the biochemical, cellular, and structural adaptations of several algae and land plant species.

Level of Performance

Stage 4 Student work is complete, and shows evidence of logical reasoning. Diagrams are detailed, correctly identify classification schemes for both algae and land plants, and include detailed comparisons of cellular and structural adaptations in both land and aquatic plants.

Stage 3 Student work shows evidence of logical reasoning but may contain minor errors or omissions. Diagrams correctly identify a classification scheme for both algae and land plants, and compare some cellular or structural adaptations.

Stage 2 Student work may be incomplete, incorrect, and may contain errors of science fact and reasoning. Diagrams correctly identify algae and land plants and develop a simple classification scheme.

Stage 1 Student work is largely incomplete, incorrect, or contains evidence of misconceptions related to plants, plant classification, and plant adaptation.

Standards Cross-References

National Science Education Standards

The great diversity of organisms is the result of more than 3.5 billion years of evolution which has filled every available niche with life forms. (Page 185)

Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their evolutionary relationships. Species is the most fundamental unit of classification. (Page 185)

Benchmarks

The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions, and a great diversity of species increases the chance that at least some living things will survive in the face of large changes in the environment. (Page 105)

The degree of kinship between organisms or species can be estimated from the similarity of their DNA sequences, which often closely matches their classification which is based on anatomical similarities. (Page 105)

Alaska Science Key Element A13

Level 4

A student who meets the content standard should understand the theory of natural selection as an explanation for evidence of changes in life forms over time (Evolution and Natural Selection).

Performance Standard Level 4, Ages 15–18

Students use the theory of natural selection to explain changes in life forms over time.

Sample Assessment Ideas

- Students watch a film about prehistoric time; retell the story using the theory of natural selection and plate tectonics.
- Students describe a modern day example of evolutionary change, such as antibiotic resistant bacteria, rapidly mutating viruses, pesticide-resistant insects, or herbicide-resistant weeds.

Expanded Sample Assessment Idea

- Students use information and evidence collected by scientists in the fields of geology, physical anthropology, embryology, molecular biology, and evolutionary biology to support the theory of change over time; apply the information to create a board game.

Procedure

Students will:

1. Assign role of geologist, physical anthropologist, embryologist, molecular biologist and evolutionary biologist to the members of their five-person team; each team member will become a subject-matter expert in their field.
2. Collect information to support the statement: "The Earth and living organisms have changed over time."
3. Each team uses collected information to create a board game entitled: "The History of Earth and Life Forms" that uses information collected in each subject matter area. Teams play each game to determine if team members understand each of the content areas.
4. Regroup in subject matter expert groups; play each game to determine accuracy of information related to their content area; rate each game for accuracy and completeness of content area knowledge.

Reflection and Revision

How could all teams have performed better during the games?

Level of Performance

Stage 4	Board game incorporates six or more pieces of information from each content area, and shows extensive evidence of knowledge related to the theory of natural selection, evolution, and change over time. Game includes detailed instructions for how to play.
Stage 3	Board game incorporates four or more pieces of information from each content area, and shows evidence of knowledge related to the theory of natural selection, evolution, and change over time. Game includes most instructions for how to play.
Stage 2	Board game uses at least two pieces of information from each content area, but shows limited evidence of knowledge related to the theory of natural selection, evolution, or change over time. Game includes limited instructions for how to play.
Stage 1	Board game is incomplete, and shows misconceptions or little evidence of understanding of natural selection, evolution, or change over time.

Standards Cross-References

National Science Education Standards

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, (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. [See Unifying Concepts and Processes] (Page 185)

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. (Page 185)

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. (Page 185)

The millions of different species of plants, animals, and microorganisms that live on Earth today are related by descent from common ancestors. (Page 185)

Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification. (Page 185)

Benchmarks

The basic idea of biological evolution is that the Earth's present-day species developed from earlier, distinctly different species. (Page 125)

Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another. (Page 125)

Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species, some of these characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely than others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase. (Page. 125)

Heritable characteristics can be observed at molecular and whole-organism levels-in structure, chemistry, or behavior. These characteristics strongly influence what capabilities an organism will have and how it will react, and therefore influence how likely it is to survive and reproduce. (Page 125)

New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells of an organism can not be passed on to the next generation. (Page 125)

Natural selection leads to organisms that are well suited for survival in particular environments. Changes alone can result in the persistence of some heritable characteristics having no survival or reproductive advantage or disadvantage for the organism. When an environment changes, the survival value of some inherited characteristics may change. (Page 125)

The theory of natural selection provides a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms. (Page 125)

Life on Earth is thought to have begun as simple, one-celled organisms about 4 billion years ago. During the first 2 billion years, only single-cell microorganisms existed, but once cells with nuclei developed about a billion years ago, increasingly complex multi-cellular organisms evolved. (Page 125)

Evolution builds on what already exists, so the more variety there is, the more there can be in the future. But evolution does not necessitate long-term progress in some set direction. Evolutionary changes appear to be like the growth of a bush: some branches survive from the beginning with little or no change, many die out altogether, and others branch repeatedly, sometimes giving rise to more complex organisms. (Page 125)

Level 4

Alaska Science Key Element A14a

A student who meets the content standard should understand the interdependence between living things and their environments (Interdependence).

Performance Standard Level 4, Ages 15–18

Students classify living organisms based on inter- and intra-community relationships, and describe how organisms and groups of organisms affect the environment.

Sample Assessment Ideas

- Students prepare a written report on an assigned plant or animal including how it affects the ecosystem in which it lives.
- Students report on the ways that plants disperse their seeds and the effect of seed dispersal on ecological succession.

Expanded Sample Assessment Idea

- Students investigate environmental problems caused by the introduction of non-indigenous plants or animals into an ecosystem.

Procedure

Students will:

1. Discuss with Elders and collect information regarding the identity and historical aspects of exogenous plants or animals that have been introduced into their locale.
2. Produce a report describing the effects of the introduction and how it has modified the local environment.

Reflection and Revision

Discuss the growth constraints and the limitations of the introduced species in the new environment. Discuss positive and negative effects of introduction of exogenous species; discuss natural invasion vs. human-mediated invasion of exogenous species.

Level of Performance

Stage 4 — Student work is complete, and shows evidence of logical reasoning. The investigation and written report show extensive evidence of knowledge related to inter- and intra-community relationships; and how the introduction of exogenous organisms affects the environment. The report explains in detail the chain of events leading to the environmental problem including species competition, animal behavior, and plant growth and development. The report shows detailed evidence of transfer and extension of knowledge in a multi-faceted discussion of natural invasion vs. human-mediated invasion of exogenous species.

Stage 3 — Student work shows evidence of logical reasoning, but may contain minor errors or omissions. The investigation and written report show evidence of knowledge related to inter- and intra-community relationships, and how the introduction of exogenous organisms affects the environment. The report explains the chain of events leading to the environmental problem some aspects of species competition, animal behavior and development, or plant growth and development. The report also shows evidence of transfer and extension of knowledge in a discussion of natural invasion vs. human-mediated invasion of exogenous species.

Stage 2 Student work is incomplete, or contains errors of science fact and reasoning. The investigation and written report show limited evidence of knowledge related to environmental problems associated with the introduction of non-indigenous organisms or the impact of human-mediated invasion vs. natural invasion.

Stage 1 Student work is largely incomplete, and contains misconceptions regarding non-indigenous organisms and the environment.

Standards Cross-References

National Science Education Standards

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. (Page 186)

Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms. (Page 186)

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 is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected. (Page 186)

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. (Page 186)

Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations. (Page 198)

The Earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that can not be renewed. (Page 198)

Humans use many natural systems as resources. Natural systems have the capacity to reuse waste, but that capacity is limited. Natural systems can change to an extent that exceeds the limits of organisms to adapt naturally or humans to adapt technologically. (Page 198)

Benchmarks

Ecosystems can be reasonably stable over hundreds of thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, and disease or parasites. If a disaster such as a flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one. (Page 117)

Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution. (Page 117)

Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. (Page 117)

Level 4

Alaska Science Key Element A14b

A student who meets the content standard should understand that the living environment consists of individuals, populations, and communities (Interdependence).

Performance Standard Level 4, Ages 15–18

Students describe plant and animal population interactions within various communities and biomes.

Sample Assessment Ideas

- Students tour a local ecosystem and write a description of the major components of that ecosystem.
- Students study the population cycles of willows and moose on Isle Royale.

Expanded Sample Assessment Ideas

- Students identify a community and create an inventory of the plant and animal species.

Procedure

Students will:

1. Choose a small, well-defined outdoor area and make an inventory of all the plants and animals they find using identification booklets and ecological survey counting techniques.
2. Work separately in their own areas, then compile the class results.
3. Determine the type of community; describe its general characteristics; identify similarities and differences between the area of class study and other communities of the same type.

Reflection and Revision

Discuss the accuracy of the survey methods. Suggest how plant and animal population interactions may differ in an aquatic vs. terrestrial environment, a marine vs. freshwater environment, a natural vs. man-made (zoo or farm) environment. Discuss how the components work together to create the ecosystem.

Level of Performance

Stage 4 Student work is complete, shows extensive evidence of knowledge of plant and animal interactions within biomes and evidence of logical reasoning. Student inventory includes: a list of most plant and animal species along with correct identification and population counts; a detailed description of the community and comparison of this specific community to the generalized biome type. Student report shows extensive transfer of knowledge and extension of knowledge in the detailed discussion of how plant and animal interactions vary in different biomes, as well as in man-made vs. natural environments.

Stage 3 Student work shows evidence of knowledge of plant and animal interactions within biomes as well as logical reasoning but may contain minor errors or omissions. Student inventory includes: a list of plant and animal species along with identification and population counts that are mostly correct; a description of the community and comparison of this specific community to the generalized biome type. Student report shows transfer of knowledge and extension of knowledge in a discussion of how plant and animal interactions vary in different biomes, or in man-made vs. natural environments.

Stage 2 Student work is incomplete, shows limited evidence of knowledge related to plant and animal interactions or characteristics of biomes and may contain errors of science fact and reasoning. Student inventory includes: a partial listing of plant and animal species along with some identification or population counts. The inventory may lack a description of the community or comparison of this specific community to the generalized biome type. A discussion of plant and animal interactions and different man-made or natural biomes may be absent.

Stage 1 Student work is largely incomplete, shows little evidence of understanding and may contain major misconceptions related to plant and animal interactions and biomes.

Standards Cross-References

National Science Education Standards

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. (Page 186)

Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms. (Page 186)

Populations grow or decline through the combined effects of births and deaths, and through emigration and immigration. Populations can increase through linear or exponential growth, with effects on resource use and environmental pollution. (Page 198)

Populations can reach limits to growth. Carrying capacity is the maximum number of individuals that can be supported in a given environment. The limitation is not the availability of space, but the number of people in relation to resources and the capacity of Earth systems to support human beings. Changes in technology can cause significant changes, either positive or negative, in carrying capacity. (Page 198)

Benchmarks

Ecosystems can be reasonably stable over hundreds of thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as a flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one. (Page 117)

Level 4

Alaska Science Key Element A14c

A student who meets the content standard should understand that a small change in a portion of an environment may affect the entire environment (Interdependence).

Performance Standard Level 4, Ages 15–18

Students describe the health of a local ecosystem using the parameters of population size, species diversity, and productivity.

Sample Assessment Ideas

- Students investigate changes in caribou population, health, and breeding grounds associated with the development of the oil industry on the North Slope of Alaska.
- Students investigate the historic biomass of a local salmon stock by comparing data from local oral histories with local, state, and federal agency data; estimate the overall health of that stock; discuss the value of using data from more than one source.

Standards Cross-References

National Science Education Standards

Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms. (Page 186)

Organisms have behavioral responses to internal changes and to external stimuli. Responses to external stimuli can result from interactions with the organism's own species and others, as well as environmental changes; these responses either can be innate or learned. The broad patterns of behavior exhibited by animals have evolved to ensure reproductive success. Animals often live in unpredictable environments, and so their behavior must be flexible enough to deal with uncertainty and change. Plants also respond to stimuli. (Page 187)

Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans. (Page 198)

Materials from human societies affect both physical and chemical cycles of the Earth. (Page 198)

Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, over-consumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and the different ways humans view the Earth. (Page 198)

Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change. (Page 199)

Benchmarks

Ecosystems can be reasonably stable over hundreds of thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, and disease or parasites. If a disaster such as a flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one. (Page 117)

Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution. (Page 117)

Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. (Page 117)

Alaska Science Key Element A15

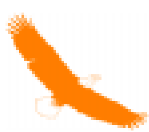
A student who meets the content standard should use science to understand and describe the local environment (Local Knowledge).

Performance Standard Level 4, Ages 15–18

Students recommend a management strategy to solve a local environmental problem related to resource utilization such as fish and game, building permits, mineral rights, and land use policies.

Sample Assessment Ideas

- Students explore the watershed management in their local area and recommend alternative strategies they think would be beneficial for the local fish and wildlife.
- Students investigate the source of the community's water and its waste disposal system; recommend improvements beneficial to the local fish and wildlife.



Expanded Sample Assessment Idea

- Students hypothesize which factors should be considered to predict when Alaska herring fisheries will open. Factors include surface water temperature, weather, wind, tides, roe percents, projected age, and so on. Students will use Internet, printed reference material, and interviews with knowledgeable people.

Procedure

Students will:

1. Collect samples of fish of specific ages; examine fish scales using a hand lens and a microscope; draw observations; write a generalization that can be used to determine the age of a fish using microscopic observations of fish scales.
2. Interview Elders, local fishermen, and knowledgeable outdoorsmen; discuss how they predict the arrival and time of spawning. Questions should include: How did they learn to look for these predicting signs? How close do their predictions usually come to actual fishery opening dates? What is the outcome when their prediction dates are wrong? What kind of "window" of correct prediction is important to them?
3. Form teams of 3–4 students with each team assigned a herring fishery; based on fishery location, the group decides which factors play primary roles in predicting the opening date of the fishery; each student on the team becomes the subject-matter expert for one or more factors.
4. Use a variety of research resources to collect information about the variables being studied, (for example, Internet, Department of Fish and Game, National Oceanographic and Aeronautic Association (NOAA) records, meteorological records, and so on).
5. Based on research, each team will predict the herring fishery opening.
6. Student predictions will be compared to actual openings.

Reflection and Revision

Based on the results of their site, teams modify their hypothesis and factors for subsequent fishery openings.

Level of Performance

Stage 4 — Student research incorporates multiple sources of information. Data collected is extensive, and relevant to the conditions at the assigned fishery site. Student's work demonstrates extensive evidence of knowledge related to environmental problem solving.

Stage 3 Student research incorporates several sources of information. Data collected is relevant to the conditions at the assigned fishery site. Student work demonstrates some evidence of knowledge related to environmental problem solving. Minor misconceptions may be evident.

Stage 2 Student research uses limited sources of information. Data collected is relevant to the conditions at the assigned fishery, but lack detail. Students work demonstrates limited evidence of knowledge related to environmental problem solving. Student work may be incomplete, incorrect, lacking detail, or contain errors of reasoning.

Stage 1 Students research may be on topic, but is limited in scope. Data shows little or no evidence relating to the assigned fishery site. Students work is largely incomplete, incorrect, and may show major misconceptions.

Standards Cross-References

National Science Education Standards

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. (Page 186)

Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms. (Page 186)

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 is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected. (Page 186)

Human populations use resources in the environment in order to maintain and improve their existence. Natural resources have been and will continue to be used to maintain human populations. (Page 198)

Humans use many natural systems as resources. Natural systems have the capacity to reuse waste, but that capacity is limited. Natural systems can change to an extent that exceeds the limits of organisms to adapt naturally or humans to adapt technologically. (Page 198)

Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans. (Page 198)

Materials from human societies affect both physical and chemical cycles of the Earth. (Page 198)

Benchmarks

The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions. A great diversity of species increases the chance that at least some living things will survive in the face of large changes in the environment. (Page 105)

Ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one. (Page 117)

Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. (Page 117)

Mini-Unit: When Will the Herring Fisheries Open?

Performance Standard A15, Level 4

Students recommend a management strategy to solve a local problem related to resource utilization such as fish and game, building permits, mineral rights. and land use policies.

Key Concepts and Skills

- The opening of commercial fisheries is directly correlated to herring sexual maturation, as measured by roe percent.
- Herring maturation is correlated to several major environmental factors, including surface water temperature, weather, wind, tides, roe percents, projected age, and so on.
- Microscopic examination of fish scales provides clues related to the age of fish.
- Weather and tides affect the time of spawning.
- Arithmetic skills include percent calculation and metric-to-American unit conversions.

Timeline

One week in early spring to design and setup experiments followed by weekly monitoring (about 1/2 hour per week) from mid-March to the end of school.

Abstract

Students design class research project that will investigate the factors used to estimate when Alaska herring fisheries will open. Each student on the team is responsible for monitoring data related to the factor or factors in which they become subject matter experts. Each student team is responsible for collecting information and data relevant to a fishery within the state.

Alaska Science Content Standard Key Element

A student who meets the content standard should use science to understand and describe the local environment (Local Knowledge).

Cross-Reference

Additional Content and Performance Standards: A4, B3, D2, and D3. Cultural Standards C2, C4, and C6.

Materials

- ✔ Access to previous harvest records including quantity and time of harvest, water temperatures, age-class outbreak of herring harvest, and stock.
- ✔ Access to Internet information on weather and herring fisheries.

Activities

1

Collect samples of fish of specific ages; examine fish scales using a hand lens and microscope; draw your observations; write a generalization that can be used to determine the age of a herring using microscopic observations of herring scales.

Embedded Assessment

Check for student understanding by examining drawings and generalizations made about the appearance of scales and age of the fish.

2

Interview Elders, local fishermen, and knowledgeable outdoorsmen; discuss how they predict the arrival of herring and time of spawning. How did they learn to look for these predicting signs? How close do their predictions usually come to actual fishery opening dates? What is the outcome when their prediction dates are wrong? What kind of "window" of correct prediction is important to them?

Embedded Assessment

After consultations, form teams of 3–4 students and assign a specific herring factory to each. Based on the factory location, the group decides which factors will play the primary role in predicting the opening date of the fishery. Each student on the team will become the subject-matter expert for one or more factors.

3

Use a variety of research resources to collect information about the variables being studied (for example, Internet, Fish and Game Department, National Oceanographic and Aeronautic Association (NOAA) records, meteorological records and so on).

Embedded Assessment

Based on research each team will predict the herring fishery opening.

4

Each team will develop a list of factors they will use to estimate the opening for each fishery being considered. Each team member is responsible for monitoring the factor or factors which they are expert in. Based on their factors they will monitor statewide weather conditions to estimate the openings of the fisheries. Student predictions will be compared to actual openings. Based on the results of their site, teams modify their hypothesis and factors for subsequent fishery openings.

Level of Performance

Stage 4 — Student research incorporates multiple sources of information. Data collected is extensive, and relevant to the conditions at the assigned fishery site. Student work demonstrates extensive evidence of knowledge related to environmental problem solving.

Stage 3 — Student research incorporates several sources of information. Data collected is relevant to the conditions at the assigned fishery site. Student work demonstrates some evidence of knowledge related to environmental problem solving. Minor misconceptions may be evident.

Stage 2 — Student research uses limited sources of information. Data collected is relevant to the conditions at the assigned fishery, but lack detail. Students work demonstrates limited evidence of knowledge related to environmental problem solving. Student work may be incomplete, incorrect, lacking detail, or contain errors of reasoning.

Stage 1 — Students research may be on topic, but is limited in scope. Data shows little or no evidence relating to the assigned fishery site. Students work is largely incomplete, incorrect, and may show major misconceptions.

Standards Cross-References

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Materials from human societies affect both physical and chemical cycles of the earth. (Page 198)

Benchmarks

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Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. (Page 117)

Level 4

Alaska Science Key Element A16

A student who meets the content standard should understand basic concepts about the Theory of Relativity, which changed the view of the universe by uniting matter and energy and by linking time with space (Relativity).

Performance Standard Level 4, Ages 15–18

Students describe how studying radioactive decay, nuclear fission, and fusion can provide evidence confirming the Law of Conservation of Matter and Energy.

Sample Assessment Ideas

- Students perform mass-energy calculations on nuclear reactions to show how the relativistic equation $E = mc^2$ predicts how much energy is released in: a radioactive decay, a nuclear fission reaction of uranium, and a nuclear fusion reaction of a deuterium (H^2) and tritium (H^3) atom; explain what degree of accuracy is required on the initial mass in order to complete such calculations.
- Students read “Relativity Visualized” by Lewis Carroll Epstein, (publisher—Insight Press, San Francisco); explain ONE of the ideas using diagram from the book.

Expanded Sample Assessment Idea

Procedure

Students will:

1. Be instructed that it is a fact that the Earth is flat. Challenge them to prove that it is not. (See attached lists for historical arguments for and against). As debate slows also say that the Earth doesn’t turn. Continue to stir up the debate. The students should leave the room debating each other and arrive in class the next day with a proof that the Earth is round and spins.
2. Be assigned one of the following people to research: Ptolemy, Copernicus, Galileo, Kepler, Newton, Tycho Brache, Albert Einstein, Stephen Hawking, Neil Armstrong, Sally Ride. Use all research avenues available, including Internet. Students should find out the personal history of the scientist as well as the major contributions to science and society.
3. Invite Elders to share beliefs and legends related to topic.
4. Develop a timeline, including the results of the previous research. The timeline should include names and important contributions, tracing the development of the geocentric view to the heliocentric view. In the development of the principles, it is very important that the societal context of the era be emphasized.
5. Hold a mock trial of Galileo that includes Ptolemy, Copernicus, Johannes Kepler, Tycho Brache, Isaac Newton, Albert Einstein, Stephen Hawking, Neil Armstrong, and Sally Ride as witnesses. “The Copernican Revolution illustrates some of the strains that can occur between science and society when science proposes ideas that seem to violate common sense or to undermine traditional values and beliefs. This part of the story should be included but not presented as the triumph of right over wrong or of science over religion.” (from Benchmarks, p. 240)

Levels of Performance

Stage 4 — Student actively participates in mock trial and demonstrates mastery of the historical-viewpoint appropriate to his / her character or position within the courtroom. Student work is correct, complete and shows evidence of logical reasoning.

Stage 3 — Student actively participates in mock trial and demonstrates knowledge of the historical-viewpoint appropriate to his / her character or position within the courtroom. Student work shows evidence of logical reasoning but may contain minor errors or omissions.

Stage 2 — Student reluctantly participates in mock trial and demonstrates limited knowledge of the historical-viewpoint appropriate to his / her character or position within the courtroom. Student work may be incomplete, incorrect and may contain errors of science fact and reasoning.

Stage 1 — Student may be a non-participant in mock trial. Student work is largely incomplete, incorrect, shows little evidence of understanding and may contain major misconceptions.

Standards Cross-References

National Science Education Standards

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. (Page 178)

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. (Page 180)

Occasionally, there are advances in science, and technology that have important and long-lasting effects on science and society. Examples of such advances include the following:

- Copernican revolution
- Newtonian mechanics
- Relativity
- Geologic time scale
- Plate tectonics
- Atomic theory
- Nuclear physics
- Biological evolution
- Germ theory
- Industrial revolution
- Molecular biology
- Information and communication
- Quantam theory
- Galactic universe
- Medical and health technology

Benchmarks

As a young man, Albert Einstein, a German scientist, formulated the special Theory of Relativity, which brought about revolutionary changes in human understanding of nature. A decade later, he proposed the general Theory of Relativity, which, along with Newton's work, ranks as one of the greatest human accomplishments in all of history. (Page 245)

Among the surprising ideas of special relativity is that nothing can travel faster than the speed of light, which is the same for all observers no matter how they or the light source happen to be moving. (Page 245)

The special Theory of Relativity is best known for stating that any form of energy has mass, and that matter itself is a form of energy. The famous relativity equation, E = mc2, holds that the transformation of even a tiny amount of matter will release an enormous amount of other forms of energy, in that the c in the equation stands for the immense speed of light. (Page 245)

General relativity theory pictures Newton's gravitational force as a distortion of space and time. (Page 245)

Many predictions from Einstein's Theory of Relativity have been confirmed on both atomic and astronomical scales. Still, the search continues for an even more powerful theory of the architecture of the universe. (Page 245)

The basic idea of mathematical modeling is to find a mathematical relationship that behaves in the same ways as the objects or processes under investigation. A mathematical model may give insight about how something really works or may fit observations very well without any intuitive meaning. (Page 270)

Mini-Unit: Copernican Revolution

Performance Standard A16, Level 4

Students describe one of the basic tenets of special relativity such as time dilation, length contraction, the space-time continuum, or The Law of Conservation of Matter and Energy.

Key Concepts and Skills

- Geocentricity, heliocentricity
- Personal histories of early astronomers (i.e. Copernicus, Galileo)
- Special Relativity
- Personal history of present-day cosmologists (i.e. Einstein, Hawking)

Timeline

10 days

Abstract

By treating relativity historically in high school, it is possible to avoid falling into the trap of trying to teach (Special Relativity's) technical and mathematical details. The main goals should be for students to see that Einstein went beyond Newton's world view by including it as a limiting case in a more complete theory. (from Benchmarks, p. 245)

This unit starts with a debate about accepted facts and ends with a mock trial of Galileo that includes input from the present day cosmologists, Albert Einstein and Stephen Hawking.

Alaska Science Content Standard Key Element

A student who meets the content standard should understand basic concepts about the Theory of Relativity, which changed the view of the universe by uniting matter and energy and by linking time with space (Relativity).

Cross-Reference

Additional Content and Performance Standards: A3, C3, C5, C6, C7. Cultural Standard A1

Materials

- ✔ Access to computers and Internet
- ✔ Library resources
- ✔ Guidelines for debate (language arts book) and mock trial

Activities

Gear-up

Tell the students that is a fact that the earth is flat. Challenge them to prove that it is not. (See attached lists for historical arguments for and against). As debate slows also say that the earth doesn't turn. Continue to stir up the debate. The students should leave the room debating each other and arrive in class the next day with a proof that the earth is round and spins.

Embedded Assessment

Listening skills, being able to validate other's opinions, etc.

1

In cooperative groups, assign one of the following to research: Ptolemy, Copernicus, Galileo, Kepler, Newton, Tycho Brache, Albert Einstein, Stephen Hawking, Neil Armstrong, Sally Ride. Use all research avenues available, including Internet. Students should find out the personal history of the scientist as well as the major contributions to science and society.

Embedded Assessment

Research skills, use of the Internet, web page analysis, working in cooperative groups, etc.

2

Invite Elders to share beliefs and legends related to topic.

3

Have students develop a timeline, including the results of the previous research. The timeline should include names and important contributions, tracing the development of the geocentric view to the heliocentric view. In the development of the principles, it is very important that the societal context of the era be emphasized.

Embedded Assessment

Content knowledge

4

Hold a mock trial of Galileo that includes Ptolemy, Copernicus, Johannes Kepler, Tycho Brache, Isaac Newton, Albert Einstein, Stephen Hawking, Neil Armstrong and Sally Ride as witnesses. "The Copernican Revolution illustrates some of the strains that can occur between science and society when science proposes ideas that seem to violate common sense or to undermine traditional values and beliefs. This part of the story should be included but not presented as the triumph of right over wrong or of science over religion." (from Benchmarks, p. 240)

Expanded Sample Assessment

Levels of Performance

Stage 4 Student actively participates in mock trial and demonstrates mastery of the historical-viewpoint appropriate to his / her character or position within the courtroom. Student work is complete, correct and shows evidence of clear and logical reasoning.

Stage 3 Student actively participates in mock trial and demonstrates knowledge of the historical-viewpoint appropriate to his / her character or position within the courtroom. Student work shows evidence of clear and logical reasoning but may contain minor errors or omissions.

Stage 2 Student reluctantly participates in mock trial and demonstrates limited knowledge of the historical-viewpoint appropriate to his / her character or position within the courtroom. Student work may be incomplete, incorrect and may contain errors of science fact and reasoning.

Stage 1 Student may be a non-participant in mock trial. Student work is largely incomplete, incorrect, shows little evidence of understanding and may contain major misconceptions.

Standards Cross-References

National Science Education Standards

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. (Pg. 178)

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. (Pg. 180)

Occasionally, there are advances in science, and technology that have important and long-lasting effects on science and society. Examples of such advances include the following: Relativity (etc.) (Pg 204)

Benchmarks

As a young man, Albert Einstein, a German scientist, formulated the special Theory of Relativity, which brought about revolutionary changes in human understanding of nature. A decade later, he proposed the general Theory of Relativity, which, along with Newton's work, ranks as one of the greatest human accomplishments in all of history. (Pg. 245)

Among the surprising ideas of special relativity is that nothing can travel faster than the speed of light, which is the same for all observers no matter how they or the light source happen to be moving. (Pg. 245)

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The basic idea of mathematical modeling is to find a mathematical relationship that behaves in the same ways as the objects or processes under investigation. A mathematical model may give insight about how something really works or may fit observations very well without any intuitive meaning. (Pg. 270)

Alaska Science Content Standard B

Level 1, Ages 15–18

A student should possess and understand the skills of scientific inquiry.

Alaska Science Key Element B1

A student who meets the content standard should use the processes of science; these processes include observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and theories, hypothesizing, predicting, and experimenting.

Performance Standard Level 4, Ages 15–18

Students collect, analyze, and interpret qualitative and quantitative data, develop models, and suggest further experimentation to investigate and explain everyday phenomena in their world.

Sample Assessment Ideas

- Students collect and analyze data about a phenomenon in their local environment (e.g., hillside slumping, erosion, frost heaves, permafrost). Students use the information to develop a model to explain the phenomenon.
- Students observe micro climates on different sides of the school building; measure variables in those micro-climates; observe and record the types and numbers of organisms present; then infer abiotic-biotic relationships.

Standards Cross-References

National Science Education Standards

Use 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. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results. (Page 175)

Formulate and revise scientific explanations and models using logic and evidence. Student inquiries should culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students should 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. (Page 175)

Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used. (Page 176)

Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations, and communicating results. (Page 176)

Results of scientific inquiry–new knowledge and methods–emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation. (Page 176)

Benchmarks

Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available). (Page 13)

Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns. (Page 13)

Alaska Science Key Element B2

A student who meets the content standard should design and conduct scientific investigations using appropriate instruments.

Performance Standard Level 4, Ages 15–18

Students conduct primary scientific research and use sophisticated instrumentation and technology to design, modify, and conduct a series of experiments related to a multifaceted problem in the natural or designed world.

Sample Assessment Ideas

- Students examine the viscosity of different oils and greases (Arctic and non-Arctic) at different temperatures. Identify possible effects of using each oil or grease on the performance of equipment operated in severe cold weather.
- Students determine what oils and wicks work best in traditional lamps. Variables to consider include effectiveness, durability; traditional oils (bear, moose, seal, walrus) and modern oils (kerosene, stove, cooking, motor).

Standards Cross-References

National Science Education Standards

Identify questions and concepts that guide scientific investigations. Students should 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. (Page 175)

Design and conduct scientific investigations. 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. (Page 175)

Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories. (Page 176)

Benchmarks

Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories. (Page 13)

Alaska Science Key Element B3

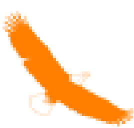
A student who meets the content standard should understand that scientific inquiry often involves different ways of thinking, curiosity, and the exploration of multiple paths.

Performance Standard Level 4, Ages 15–18

Students conduct research and media searches that highlight forms of inquiry and multiple solutions to complex problems.

Sample Assessment Ideas

- Students read recent scientific research and reviews of that research to examine suggestions for improvement.
- Local students conduct independent parallel investigations with a student team in a different location on the same research question, compare results, and discuss the processes used to arrive at their respective conclusions.



Expanded Sample Assessment

- Students use primary and secondary research to determine an ideal method for tanning salmon skins in their locality and describe how they arrived at that result.

Procedure

Students will:

1. Investigate salmon skin tanning, including reasons for tanning, why skins and hides are tanned, and traditional and modern methods of tanning.
2. Brainstorm about types of information that might be useful in solving the problem.
3. Divide into small groups to investigate the problem from different perspectives (conduct experiments with skins and hides, interview Elders and professional tanners, research Internet).
4. Share the research results with each other, critique each method of tanning, and develop alternative methods of tanning.

Reflection and Revision

Reflect on ways in which collaboration, creativity, multiple paths of exploration, and personal integrity helped to solve the problem.

Level of Performance

Stage 4 — Student work is complete, correct and shows evidence of elaboration and extension. Student uses multiple sources to identify reasonable solutions to the tanning task including Internet research, and local interviews; designed controlled, quantitative experiments.

Stage 3 — Student work is generally complete, correct and shows some evidence of elaboration and extension. Student uses multiple sources to identify solutions to the tanning task including Internet research and local interviews. Although experimentation is included, it may be poorly controlled, lack quantitative measurements or result in a questionable solution to the tanning task.

Stage 2 — Student work is generally on task but shows little evidence of elaboration. Student may use one or two sources to identify solutions to the tanning task. Although experimentation is included, controls and measurements are lacking.

Solutions, if included, may not be related to the experimental procedure presented.

Stage 1 Student work may be related to tanning but is not targeted to identify multiple solutions to the tanning task. Experiments and use of outside information sources, if included, may not be appropriate or useful.

Standards Cross-References

National Science Education Standards

Recognize and analyze alternative explanations and models. 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 should be able to use scientific criteria to find the preferred explanations. (Page 175)

Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists. (Page 176)

Benchmarks

Know why curiosity, honesty, openness, and skepticism are so highly regarded in science and how they are incorporated into the way science is carried out; exhibit those traits in their own lives and value them in others. (Page 287)

Level 4

Alaska Science Key Element B4

A student who meets the content standard should understand that personal integrity, skepticism, openness to new ideas, creativity, collaborative effort, and logical reasoning are all aspects of scientific inquiry.

Performance Standard Level 4, Ages 15–18

Students work in collaborative groups to collect and analyze their experimental results. They conduct media searches and use the information to support their experimental design or experimental evidence.

Sample Assessment Ideas

- Students locate sources of drinking water; test the quality of the water (salinity, pH, turbidity, lead content, microorganism presence, taste); develop a rating scale for potability; and share their methods and results.
- Students determine the energy content of different foods using experimental calorimetric methods. They compare their results to published standards.

Standards Cross-References

National Science Education Standards

Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge. (Page 176)

Benchmarks

Know why curiosity, honesty, openness, and skepticism are so highly regarded in science and how they are incorporated into the way science is carried out; exhibit those traits in their own lives and value them in others. (Page 287)

View science and technology thoughtfully, being neither categorically antagonistic nor uncritically positive. (Page 287)

Be aware, when considering claims, that when people try to prove a point, they may select only the data that support it and ignore any that would contradict it. (Page 300)

Level 4

Alaska Science Key Element B5

A student who meets the content standard should employ ethical standards, including unbiased data collection and factual reporting of results.

Performance Standard Level 4, Ages 15–18

Students discuss the validity of assertions made in primary and secondary scientific sources by analyzing and critiquing the data used as evidence to support those assertions.

Sample Assessment Ideas

- Students research whether or not President Thomas Jefferson's descendants include African American descendants of Sally Hemmings, and critique the research used to generate the data that supports both pro and con assertions.
- Students critique the research used to support pro and con arguments in debates regarding quality of life issues (e.g., plastic vs. paper, fluoridation of drinking water, use of mercury in dental fillings). Special attention should be given to validity and reproducibility.

Standards Cross-References

National Science Education Standards

Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation. (Page 176)

Scientists have ethical traditions. Scientists value peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work. Violations of such norms do occur, but scientists responsible for such violations are censured by their peers. (Page 200)

Benchmarks

Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings. For that reason, scientific teams are expected to seek out the possible sources of bias in the design of their investigations and in their data analysis. Checking each other's results and explanations helps, but that is no guarantee against bias. (Page 13)

Current ethics in science hold that research involving human subjects may be conducted only with the informed consent of the subjects, even if this constraint limits some kinds of potentially important research or influences the results. When it comes to participation in research that could pose risks to society, most scientists believe that a decision to participate or not is a matter of personal ethics rather than professional ethics. (Page 19)

Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects. Outside their areas of expertise, however, scientists should enjoy no special credibility. And where their own personal, institutional, or community interests are at stake, scientists as a group can be expected to be no less biased than other groups are about their perceived interests. (Page 19)

Notice and criticize arguments based on the faulty, incomplete, or misleading use of numbers, such as in instances when (1) average results are reported, but not the amount of variation around the average, (2) a percentage or fraction is given, but not the total sample size (as in “9 out of 10 dentists recommend . . . ”), (3) absolute and proportional quantities are mixed (as in “3,400 more robberies in our city last year, whereas other cities had an increase of less than 1%), or (4) results are reported with overstated precision (as in representing 13 out of 19 students as 68.42%). (Page 300)

Check graphs to see that they do not misrepresent results by using inappropriate scales or by failing to specify the axes clearly. (Page 300)

Insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position being taken, whether one’s own or that of others, can be judged. (Page 300)

Alaska Science Key Element B6

A student who meets the content standard should employ strict adherence to safety procedures in conducting scientific investigations.

Performance Standard Level 4, Ages 15–18

Students examine laboratory and community safety procedures, identify how an individual affects the safety of the group, and practice safe behavior in the classroom and laboratory.

Sample Assessment Ideas

- Students review the risks associated with medical wastes, and accurately identify the hazards of contaminated fomites.
- Students demonstrate proper techniques of lab safety while determining properties of four unknown, clear, colorless liquids (pH, conductivity, flammability, odor).

Standards Cross-References

National Science Education Standards

Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability, or death may be present. Humans have a variety of mechanisms—sensory, motor, emotional, social, and technological—that can reduce and modify hazards. (Page 197)

Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards ranging from those with minor risk to a few people to major catastrophes with major risk to many people. The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations. (Page 199)

Benchmarks

Benefits and costs of proposed choices include consequences that are long-term as well as short-term, and indirect as well as direct. The more remote the consequences of a personal or social decision, the harder it usually is to take them into account in considering alternatives. But benefits and costs may be difficult to estimate. (Page 166)

Social trade-offs are often generational. The costs of benefits received by one generation may fall on subsequent generations. Also, the cost of a social trade-off is sometimes borne by one generation although the benefits are enjoyed by their descendants. (Page 166)

Alaska Science Content Standard C

Level 1, Ages 15–18

A student should understand the nature and history of science.

Level 4

Alaska Science Key Element C1

A student who meets the content standard should know how the words “fact,” “observation,” “concept,” “principle,” “law,” and “theory” are generally used in the scientific community.

Performance Standard Level 4, Ages 15–18

Students can differentiate among facts, observations, concepts, principles, laws, and theories, as used in science publications.

Sample Assessment Ideas

- Students define and give examples of the terms commonly used in the scientific community; differentiate how those same terms are defined and used in a non-scientific setting.
- Students analyze a newspaper or magazine article on a science topic, identifying facts, concepts, laws and theories.

Standards Cross-References

National Science Education Standards

Communicate and defend a scientific argument. Students in school science programs should 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. (Page 176)

Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world. (Page 201)

Benchmarks

Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere. The rules may range from very simple to extremely complex, but scientists operate on the belief that the rules can be discovered by careful, systematic study. (Page 8)

No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions. (Page 8)

Alaska Science Key Element C2

A student who meets the content standard should understand that scientific knowledge is validated by specific experiments that conclude in similar results.

Performance Standard Level 4, Ages 15–18

Students evaluate the validity of experimental findings.

Sample Assessment Ideas

- Students critique the research used to support pro and con arguments in debates regarding quality of life issues (e.g., plastic vs. paper, fluoridations of drinking water, use of mercury in dental fillings). Special attention should be given to validity and reproducibility.
- Students investigate research done by the Department of Fish and Game or Federal biologists on predicted salmon runs. Students compare data and conclusions with previous years' predictions and actual runs.

Standards Cross-Reference

National Science Education Standards

Recognize and analyze alternative explanations and models. 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 should be able to use scientific criteria to find the preferred explanations. (Page 175)

Results of scientific inquiry—new knowledge and methods-emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation. (Page 176)

Benchmarks

Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings. For that reason, scientific teams are expected to seek out the possible sources of bias in design of their investigations and in their data analysis. Checking each other's results and explanations helps but that is no guarantee against bias. (Page 13)

Wonder how likely it is that some event of interest might have occurred just by chance. (Page 300)

Insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position being taken—whether one's own or that of others'—can be judged. (Page 300)

Suggest alternative ways of explaining data and criticize arguments in which data, explanations, or conclusions are represented as the only ones worth consideration, with no mention of other possibilities. Similarly, suggest alternative trade-offs in decisions and designs, and criticize those in which major trade-offs are not acknowledged. (Page 300) for further investigation. (Page 176)

Level 4

Alaska Science Key Element C3

A student who meets the content standard should understand that society, culture, history, and environment affect the development of scientific knowledge.

Performance Standard Level 4, Ages 15–18

Students describe how human society, culture, history, and environment have influenced the development of scientific thinking.

Sample Assessment Ideas

- Students prepare reports on instances where society has repressed scientific knowledge or instances where it has supported and encouraged scientific knowledge (e.g., Galileo, Chinese Cultural Revolution, the National Science Foundation).
- Students prepare reports on instances in Alaska where society has influenced the gathering or use of scientific information, indentifying the influences, and their outcome (e.g., the C. Thompson Study).

Standards Cross-Reference

National Science Education Standards

Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology. (Page 199)

Scientists are influenced by the societal, cultural, and personal beliefs and ways of viewing the world. Science is not separate from society but rather science is a part of society. (Page 201)

In history, diverse cultures have contributed scientific knowledge and technologic inventions. Modern science began to evolve rapidly in Europe several hundred years ago. During the past two centuries, it has contributed significantly to the industrialization of Western and non-Western cultures. However, other non-European cultures have developed scientific ideas and solved human problems through technology. (Page 201)

Benchmarks

The early Egyptian, Greek, Chinese, Hindu, and Arabic cultures are responsible for many scientific and mathematical ideas and technological inventions. (Page 19)

Modern science is based on traditions of thought that came together in Europe about 500 years ago. People from all cultures now contribute to the tradition. (Page 19)

Progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments. (Page 19)

Level 4

Alaska Science Key Element C4

A student who meets the content standard should understand that some personal and societal beliefs accept non-scientific methods for validating knowledge.

Performance Standard Level 4, Ages 15–18

Students investigate societal (non-scientific) beliefs of multiple communities or cultures regarding a phenomenon.

Sample Assessment Ideas

- Students use multiple sources (oral and written histories, contact with classrooms, and cultures around the world) to compile various beliefs.
- Students discuss the possible origin of each belief.

Standards Cross-Reference

National Science Education Standards

Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism as scientists strive for the best possible explanations about the natural world. (Page 201)

Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public. Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful an socially relevant, but they are not scientific. (Page 201)

Because all science ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore unlikely to change in the areas in which they have been tested. In areas where data or understanding is incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest. (Page 201)

The historical perspective of scientific explanations demonstrates how scientific knowledge changes by evolving over time, almost always building on earlier knowledge. (Page 204)

Benchmarks

Cultural beliefs strongly influence the values and behavior of the people who grow up in the culture, often without their being fully aware of it. Response to these influences varies among individuals. (Page 156)

Level 4

Alaska Science Key Element C5

A student who meets the content standard should understand that sharing scientific discoveries is important to influencing individuals and society and in advancing scientific knowledge.

Performance Standard C5, Level 4 Ages 15–18

Students use personal and group experiences as well as media searches to synthesize data derived from multiple perspectives to study a multifaceted problem related to state, regional, or global concerns and post their results for review.

Sample Assessment Ideas

- Students estimate the carrying capacity of a township (or given area); teams make land-use maps of traditional or existing uses; identify and predict the effects of human impact; publish the results for township comment.
- Students use a forum to discuss whether the global climate is changing due to the greenhouse effect, or if recent climate variations are part of normal long-term phenomena. (Students utilize research data when expressing their point of view.)

Expanded Sample Assessment Idea

- Students collect information about landfill; design an improved landfill appropriate for their locale; present their designs to the local planning commission.

Procedure

Student group will

1. Collect information about their local landfill.
2. Research landfill designs in other communities.
3. Discuss the current landfill in terms of location, use, type of material in landfill, and how long it will take to fill it.
4. Design a landfill appropriate for their locale. Facts to be considered include porosity and permeability of the soil, interpretation of aerial images (if available), type of material landfill will hold, calculations required to determine landfill size, location of new site and cost consideration.
5. Present their suggested designs to the local planning commission.

Reflection and Revision

Use the planning commission response to revise landfill design.

Level of Performance

Stage 4	Landfill design and justification documents are complete, detailed and show evidence of elaboration, extension, higher-order thinking skills and relevant knowledge.
Stage 3	Landfill design and justification documents are complete and clearly expressed although minor inaccuracies, omissions or inappropriateness may also be evident.
Stage 2	Landfill design and justification documents may contain some elements of proficient work but may be incomplete, inaccurate, or inappropriate for the locale.
Stage 1	Landfill design is incomplete, inaccurate or inappropriate for the locale. Justification documents, if included, lack detail and contain little evidence of relevant knowledge.

Standards Cross-References

National Science Education Standards

Communicate and defend a scientific argument. Students in school science programs should 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. (Page 176)

Results of scientific inquiry-new knowledge and methods-emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation. (Page 176)

Scientists have ethical traditions. Scientists value peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work. Violations of such norms do occur, but scientists responsible for such violations are censured by their peers. (Page 200)

Usually changes in science occur as small modifications in extant knowledge. The daily work of science and engineering results in incremental advances in our understanding of the world and our ability to meet human needs and aspirations. Much can be learned about the internal workings of science and the nature of science from study of individual scientists, their daily work, and their efforts to advance scientific knowledge in their area of study. (Page 201)

Benchmarks

Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings. For that reason, scientific teams are expected to seek out the possible sources of bias in the design of their investigations and in their data analysis. Checking each other's results and explanations helps, but that is no guarantee against bias. (Page 13)

New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators. (Page 13)

Level 4

Alaska Science Key Element C6

A student who meets the content standard should understand that scientific discovery is often a combination of an accidental happening and observation by a knowledgeable person with an open mind.

Performance Standard Level 4, Ages 15–18

Students describe how current research is changing accepted scientific theories.

Sample Assessment Ideas

- Students use a forum to discuss current ideas about the transmission of communicable diseases.
- Students conduct an Internet search on a recent scientific discovery (e.g., development of a new drug treatment, in-utero surgery, genetic engineering) and its effect on current scientific practice.

Standards Cross-References

National Science Education Standards

Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. (Page 192)

Creativity, imagination, and a good knowledge base are all required in the work of science and engineering. (Page 192)

Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore unlikely to change in the areas in which they have been tested. In areas where data or understanding are incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest. (Page 201)

Benchmarks

There are different traditions in science about what is investigated and how, but they all have in common certain basic beliefs about the value of evidence, logic, and good arguments. And there is agreement that progress in all fields of science depends on intelligence, hard work, imagination, and even chance. (Page 13)

New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators. (Page 13)

Level 4

Alaska Science Key Element C7

A student who meets the content standard should understand that major scientific breakthroughs may link large amounts of knowledge, build upon the contributions of many scientists, and cross different lines of study.

Performance Standard Level 4, Ages 15–18

Students identify the research, contributions, discoveries, and collaborative efforts currently underway to solve a scientific, industrial, mechanical, agricultural, or medical problem.

Sample Assessment Ideas

- Students use the Internet and other research tools to compare and contrast how different nations and cultures are responding to the population crisis around the world (e.g., area of declining population, overpopulation, an aging population, etc.)
- Students present the findings of the Human Genome Project; discuss uses for the new information.

Standards Cross-References

National Science Education Standards

Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world. (Page 192)

Occasionally, there are advances in science and technology that have important and long lasting effects on science and society. Examples of such advances include the following: Copernican revolution, Newtonian mechanics, relativity, geologic time scale, plate tectonics, atomic theory, nuclear physics, biological evolution, germ theory, industrial revolution, molecular biology, information and communication, quantum theory, galactic universe, medical and health technology. (Page 204)

Benchmarks

From time to time, major shifts occur in the scientific view of how the world works. More often however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Change and continuity are persistent features of science. (Page 8)

New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators. (Page 13)

Science disciplines differ from one another in what is studied, techniques used, and outcomes sought, but they share a common purpose and philosophy, and all are part of the same scientific enterprise. Although each discipline provides a conceptual structure for organizing and pursuing knowledge, many problems are studied by scientists using information and skills from many disciplines. Disciplines do not have fixed boundaries, and it happens that new scientific disciplines are being formed where existing ones meet and that some sub-disciplines spin off to become new disciplines in their own right. (Page 19)

Level 4

Alaska Science Key Element C8

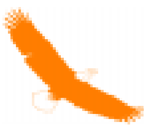
A student who meets the content standard should understand that acceptance of a new idea depends upon supporting evidence and that new ideas that conflict with beliefs or common sense are often resisted.

Performance Standard Level 4, Ages 15–18

Students analyze the evidence used to support current or historic scientific understanding of an issue as well as the evidence used to support ideas contrary to current scientific understanding.

Sample Assessment Ideas

- Students analyze the evidence, pro and con, that the HIV virus causes AIDS.
- Students analyze the evidence that supports and refutes the idea that the first peoples of the Western Hemisphere arrived via a frozen Bering Sea land bridge.



Expanded Sample Assessment Idea

- Students choose a commonly held traditional belief that may cause resistance to scientific evidence. Defend a point of view that respects that belief while maintaining an open mind toward scientific evidence.

Procedure

Students will:

1. Choose and research traditional beliefs about the natural world.
2. Share and discuss ideas in pairs or small groups.
3. Do research about the scientific evidence regarding the phenomenon.
4. Write a paper to defend a point of view about the belief.

Reflection and Revision

Modify viewpoint to incorporate anticipated scientific studies.

Level of Performance

Stage 4 — Student demonstrates extensive understanding of traditional beliefs, societal viewpoints and scientific evidence regarding a phenomenon of the natural world. Student defends a position and maintains an open mind toward the opposing evidence or belief.

Stage 3 — Student demonstrates a clear understanding of traditional beliefs, societal viewpoints and scientific evidence regarding a phenomenon of the natural world. Student defends a position but may choose to ignore certain aspects of the opposing evidence or belief.

Stage 2 — Student demonstrates an understanding of traditional beliefs, societal viewpoints or scientific evidence regarding a phenomenon of the natural world. Student defends a position but ignores or belittles the opposing evidence or belief.

Stage 1 — Student demonstrates a limited understanding of traditional beliefs, societal viewpoints or scientific evidence regarding a phenomenon of the natural world. Student defense of a position lacks detail and contains errors and misconceptions regarding the evidence or beliefs.

Standards Cross-References

National Science Education Standards

Recognize and analyze alternative explanations and models. 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 should be able to use scientific criteria to find the preferred explanations. (Page 175)

Communicate and defend a scientific argument. Students in school science programs should 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. (Page 176)

Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge. (Page 176)

Scientists are influenced by societal, cultural, and personal beliefs and ways of viewing the world. Science is not separate from society but rather science is a part of society. (Page 201)

Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore unlikely to change in the areas in which they have been tested. In areas where data or understanding are incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest. (Page 201)

Benchmarks

No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a broader range of observations. In science, the testing, revising, and the occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions. (Page 8)

In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism. In the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings. (Page 13)

New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly through contributions from many investigators. (Page 13)

APPLICATION

Alaska Science Content Standard D

Level 1, Ages 15–18

A student should be able to apply scientific knowledge and skills to make reasoned decisions about the use of science and scientific innovations.

Level 4

Alaska Science Key Element D1

A student who meets the content standard should apply scientific knowledge and skills to understand issues and everyday events.

Performance Standard Level 4, Ages 15–18

Students investigate a regional or global issue; identify and evaluate the current solutions.

Sample Assessment Ideas

- Students study parasitic infection affecting food stuffs (e.g., moose, caribou, wheat, rye, peanuts); assess methods for eradication of the parasite.
- Students research oil exploration in Alaska and across the globe; compare the different methods.

Standards Cross-References

National Science Education Standards

Formulate and revise scientific explanations and models using logic and evidence. Student inquiries should culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students should 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. (Page 175)

Recognize and analyze alternative explanations and models. 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 should be able to use scientific criteria to find the preferred explanations. (Page 175)

Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge. (Page 176)

Benchmarks

Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects. Outside their areas of expertise, however, scientists should enjoy no special credibility. And where their own personal, institutional, or community interests are at stake, scientists as a group can be expected to be no less biased than other groups are about their perceived interests. (Page 19)

Level 4

Alaska Science Key Element D2

A student who meets the content standard should understand that scientific innovations may affect our economy, safety, environment, health, and society and that these effects may be short-term or long-term, positive or negative, and expected or unexpected.

Performance Standard Level 4, Ages 15–18

Students research a current problem and conduct a cost and benefit analysis associated with both the problem and potential solutions.

Sample Assessment Ideas

- Students look back on the Y2K issue, and evaluate the impact of the two-digit date on some aspect of our lives.
- Students evaluate the potential positive and negative consequences of recombinant genetics (gene-splicing) in food organisms.

Expanded Sample Assessment Idea

- Students study the risks associated with nuclear power reactors and evaluate various safety, clean-up and waste storage strategies.

Procedure

Students will:

1. Use primary and secondary sources to research safety at several nuclear power facilities (including Chernobyl, Three Mile Island, and plants with no history of mishaps).
2. Evaluate the merits of current safety, clean-up and waste-storage strategies.
3. Compile and share their findings.
4. Independently adopt a waste storage strategy and defend their position in a class discussion.

Reflection and Revision

Revise their position based on arguments from other class members.

Level of Performance

Stage 4	Student uses both primary and secondary sources in researching nuclear power facilities. Student waste storage strategy shows evidence of higher-order thinking and is elaborate.
Stage 3	Student uses either primary or secondary sources in researching nuclear power facilities. Student waste storage strategy shows limited evidence of elaboration or higher-order thinking and may contain minor errors or inaccuracies.
Stage 2	Student uses minimal information to research nuclear power facilities. Student waste storage strategy is incomplete and may show errors of scientific fact, inaccuracies or misconceptions.
Stage 1	Student relies on previous knowledge or biased opinions to collect information about nuclear power facilities. The storage strategy lacks adequate detail and shows evidence of serious misconceptions.

Standards Cross-References

National Science Education Standards

Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology related challenges. However, understanding science alone will not resolve local, national or global challenges. (Page 199)

Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them. Students should understand the appropriateness and value of basic questions "What can happen?" "What are the odds?" and "How do scientists and engineers know what will happen?" (Page 199)

Benchmarks

Technology usually affects society more directly than science because it solves practical problems and serves human needs (and may create new problems and needs). In contrast, science affects society mainly by stimulating and satisfying people's curiosity and occasionally by enlarging or challenging their views of what the world is like. (Page 47)

In deciding on proposals to introduce new technologies or to curtail existing ones, some key questions arise concerning alternatives, risks, costs, and benefits. What alternative ways are there to achieve the same ends, and how do the alternatives compare to the plan being put forward? Who benefits and who suffers? What are the financial and social costs, do they change over time, and who bears them? What are the risks associated with using (or not using) the new technology, how serious are they, and who is in jeopardy? What human, material, and energy resources will be needed to build, install, operate, maintain, and replace the new technology, and where will they come from? How will the new technology and its waste products be disposed of and at what costs? (Page 57)

Level 4

Alaska Science Key Element D3

A student who meets the content standard should recommend solutions to everyday problems by applying scientific knowledge and skills.

Performance Standard Level 4, Ages 15–18

Students conduct independent research investigations about a community issue and propose a solution based on their original data.

Sample Assessment Ideas

- Students research the issues involved with commercial fishing bycatch and design possible solutions.
- Students examine and quantify the “daily trash accumulation” for the school; calculate the mass and volume of recyclable and non-recyclable materials. Determine the economic feasibility of creating separate waste repositories.

Standards Cross-References

National Science Education Standards

Identify a problem or design an opportunity. Students should be able to identify new problems or needs and propose ways to change and improve current technological designs. (Page 192)

Propose designs and choose between alternative solutions. Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. (Page 192)

Implement a proposed design. A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials such as wood, metal, plastics, and textiles. Solutions can also be implemented using computer software. (Page 192)

Evaluate the solution and its consequences. Students should test any solution against the needs and criteria it was designed to meet. At this stage, new criteria not originally considered may be reviewed. (Page 192)

Benchmarks

In designing a device or process, thought should be given as to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design. (Page 52)

Level 4

Alaska Science Key Element D4

A student who meets the content standard should evaluate the scientific and social merits of solutions to everyday problems.

Performance Standard Level 4, Ages 15–18

Students evaluate scientific and societal impacts of developing technologies.

Sample Assessment Ideas

- Students evaluate the impact of a developing technology (e.g., new or smaller computers, nanotechnology, self-guided vehicles, Global Positioning System in vehicles, cellular communication devices, fetal surgery, genetic manipulation of plant genomes, cloning).
- Students evaluate the issues surrounding organ transplant with regard to minority populations.

Standards Cross-References

National Science Education Standards

Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world. (Page 192)

Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, over-consumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the Earth. (Page 198)

Human activities can enhance potential for hazards. Acquisition of resources, urban growth, and waste disposal can accelerate rates of natural change. (Page 199)

Natural and human-induced hazards present the need for humans to assess potential danger and risk. Many changes in the environment designed by humans bring benefits to society, as well as cause risks. Students should understand the costs and trade-offs of various hazards ranging from those with minor risk to a few people to major catastrophes with major risk to many people. The scale of events and accuracy with which scientists and engineers can (and cannot) predict events are important considerations. (Page 199)

Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology related challenges. However, understanding science alone will not resolve local, national or global challenges. (Page 199)

Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology. (Page 199)

Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them. Students should understand the appropriateness and value of basic questions: "What can happen?" "What are the odds?" and "How do scientists and engineers know what will happen?" (Page 199)

Humans have a major effect on other species. For example, the influence of humans on other organisms occurs through land use which decreases space available to other species—and pollution—which changes the chemical composition of air, soil, and water. (Page 199)

Benchmarks

In deciding on proposals to introduce new technologies or to curtail existing ones, some key questions arise concerning alternatives, risks, costs, and benefits. What alternative ways are there to achieve the same ends, and how do the alternatives compare to the plan being put forward? Who benefits and who suffers? What are the financial and social costs, do they change over time, and who bears them? What are the risks associated with using (or not using) the new technology, how serious are they, and who is in jeopardy? What human, material, and energy resources will be needed to build, install, operate, maintain, and replace the new technology, and where will they come from? How will the new technology and its waste products be disposed of and at what costs? (Page 57)

Human inventiveness has brought new risks as well as improvements to human existence. (Page 57)

Level 4

Alaska Science Key Element D5

A student who meets the content standard should participate in reasoned discussions of public policy related to scientific innovation and proposed technological solutions to problems.

Performance Standard Level 4, Ages 15–18

Students propose a scientifically or technologically based change to public policy at the local, state, or national level and share their proposal with an audience of those affected by the issue as well as those involved in policy-making decisions.

Sample Assessment Ideas

- Students monitor and suggest ways to improve the water quality in and around their locale.
- Students research and discuss new technologies and the ethics of genetic engineering with other students via the Internet; conduct a class debate on the issue; and write a letter to the National Institute of Health on their position.

Standards Cross-References

National Science Education Standards

Hazards and the potential for accidents exist. Regardless of the environment, the possibility of injury, illness, disability, or death may be present. Humans have a variety of mechanisms—sensory, motor, emotional, social, and technological—that can reduce and modify hazards. (Page 197)

Materials from human societies affect both physical and chemical cycles of the Earth. (Page 198)

Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, over-consumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the Earth. (Page 198)

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The human species has a major impact on other species in many ways: reducing the amount of the Earth's surface available to those other species; interfering with their food sources, changing the temperature and chemical composition of their habitats; introducing foreign species into their ecosystems, and altering organisms directly through selective breeding and genetic engineering. (Page 57)

Humans inventiveness has brought new risks as well as improvements to human existence. (Page 57)

Alaska Science Key Element D6

A student who meets the content standard should act upon reasoned decisions and evaluate the effectiveness of the action.

Performance Standard Level 4, Ages 15–18

Students work collaboratively to design a solution to a problem, develop an evaluation tool to measure the effectiveness of their solution, and make revisions to the original solution based on the information collected.

Sample Assessment Ideas

- Students identify the greatest sources of physical injury in the community; design a public awareness program for lowering risks, evaluate the result after informing the public.
- Students examine various shampoos; evaluate which one works the best with the local water supply.

Standards Cross-References

National Science Education Standards

Formulate and revise scientific explanations and models using logic and evidence. Student inquiries should culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students should 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. (Page 175)

Recognize and analyze alternative explanations and models. 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 should be able to use scientific criteria to find the preferred explanations. (Page 175)

Identify a problem or design an opportunity. Students should be able to identify new problems or needs and to change and improve current technological designs. (Page 192)

Propose designs and choose between alternative solutions. Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes. (Page 192)

Implement a proposed design. A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials (e.g., wood, metal, plastics, and textiles). Solutions can also be implemented using computer software. (Page 192)

Evaluate the solution and its consequences. Students should test any solution against the needs and criteria it was designed to meet. At this stage, new criteria not originally considered may be reviewed. (Page 192)

Benchmarks

Social and economic forces strongly influence which technologies will be developed and used. Which will prevail is affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition, and tax incentives. (Page 57)

Human inventiveness has brought new risks as well as improvements to human existence. (Page 57)