Tennessee Academic Standards for Science

Tennessee Science Standards Value Statement

Tennessee possesses a citizenry known to be intelligent, knowledgeable, hardworking, and creative. Tennessee's schools offer science programs that introduce a broad range of important subjects along with opportunities to explore topics ranging from nuclear energy science to breakthrough medical discoveries. The challenge of developing and sustaining a population of scientifically informed citizens requires that educational systems be guided by science curriculum standards that are academically rigorous, relevant to today's world, and attendant to what makes Tennessee a unique place to live and learn.

To achieve this end, school systems employ standards to craft meaningful local curricula that are innovative and provide myriad learning opportunities that extend beyond mastery of basic scientific principles. The Tennessee Academic Standards for Science standards include the necessary qualities and conditions to support learning environments in which students can develop knowledge and skills needed for post-secondary and career pursuits, and be well-positioned to become curious, lifelong learners.

Declarations:

Tennessee's K-12 science standards are intended to guide the development and delivery of educational experiences that prepare all students for the challenges of the 21st century and enable them to:

- Develop an in-depth understanding of the major science disciplines through a series of coherent K-12 learning experiences that afford frequent interactions with the natural and man-made worlds;
- Make pertinent connections among scientific concepts, associated mathematical principles, and skillful applications of reading, writing, listening, and speaking;
- Recognize that certain broad concepts/big ideas foster a comprehensive and scientifically-based picture of the world and are important across all fields of science;
- Explore scientific phenomena and build science knowledge and skills using their own linguistic and cultural experiences with appropriate assistance or accommodations;
- Identify and ask appropriate questions that can be answered through scientific investigations;
- Design and conduct investigations independently or collaboratively to generate evidence needed to answer a variety of questions;
- Use appropriate equipment and tools and apply safe laboratory habits and procedures;
- Think critically and logically to analyze and interpret data, draw conclusions, and develop explanations that are based on evidence and are free from bias;
- Communicate and defend results through multiple modes of representation (e.g., oral, mathematical, pictorial, graphic, and textual models);
- Integrate science, mathematics, technology, and engineering design to solve problems and guide everyday decisions;
- Consider trade-offs among possible solutions when making decisions about issues for which there

are competing alternatives;

- Locate, evaluate, and apply reliable sources of scientific and technological information;
- Recognize that the principal activity of scientists is to explain the natural world and develop associated theories and laws;
- Recognize that current scientific understanding is tentative and subject to change as experimental evidence accumulates and/or old evidence is reexamined;
- Demonstrate an understanding of scientific principles and the ability to conduct investigations through student-directed experiments, authentic performances, lab reports, portfolios, laboratory demonstrations, real world projects, interviews, and high-stakes tests.[1]

[1] Information from the NSTA Position Statements was adapted to compile this document.

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Research and Vision of the Standards

The ideas driving the development of the standards are:

- Improve the coherence of content from grade to grade.
- Integrate disciplinary core ideas with crosscutting concepts and science and engineering practices.
- Promote equity and diversity of science and engineering education for all learners.

Disciplinary Core Ideas and Components:

The *Framework for K-12 Science Education* describes the progression of disciplinary core ideas (DCIs) and gives grade level end points. These core ideas and the component ideas are the structure and organization of the Tennessee Academic Standards for Science. Focusing on a limited number of ideas, grades K-12 will deepen content knowledge and build on learning. The progressions are designed to build on student understanding of science with developmental appropriateness. The science and engineering practices are integrated throughout the physical, life, and earth DCI groups shown below.

***PHYSICAL SCIENCES* (PS)**

PS1: Matter and Its Interactions

A. Structure and Properties of Matter
B. Chemical Processes
C. Nuclear Processes

PS2: Motion and Stability: Forces and Interactions

A. Forces, Fields, and Motion
B. Types of Interactions
C. Stability and Instability in Physical Systems

PS3: Energy

A. Definitions of Energy
B. Conservation of Energy and Energy Transfer
C. Relationship Between Energy and Forces and Fields
D. Energy in Chemical Processes and Everyday Life

PS4: Waves and Their Applications in Technologies for Information Transfer

A. Wave Properties: Mechanical and Electromagnetic
B. Electromagnetic Radiation
C. Information Technologies and Instrumentation

LIFE SCIENCES **(LS)**

LS1: From Molecules to Organisms: Structures and Processes

A. Structure and Function
B. Growth and Development of Organisms
C. Organization for Matter and Energy Flow in Organisms
D. Information Processing

LS2: Ecosystems: Interactions, Energy, and Dynamics

A. Interdependent Relationships in Ecosystems
B. Cycles of Matter and Energy Transfer in Ecosystems
C. Ecosystem Dynamics, Functioning, and Resilience
D. Social Interactions and Group Behavior

LS3: Heredity: Inheritance and Variation of Traits

A. Inheritance of Traits
B. Variation of Traits

LS4: Biological Change: Unity and Diversity

A. Evidence of Common Ancestry
B. Natural Selection
C. Adaptation
D. Biodiversity and Humans

EARTH AND SPACE SCIENCES **(ESS)**

ESS1: Earth's Place in the Universe

A. The Universe and Its Stars
B. Earth and the Solar System
C. The History of Planet Earth

ESS2: Earth's Systems

A. Earth Materials and Systems
B. Plate Tectonics and Large-Scale System Interactions
C. The Roles of Water in Earth's Surface Processes
D. Weather and Climate
E. Biogeology

ESS3: Earth and Human Activity

A. Natural Resources
B. Natural Hazards
C. Human Impacts on Earth Systems
D. Global Climate Change

ENGINEERING, TECHNOLOGY, AND APPLICATIONS OF SCIENCE **(ETS)**

ETS1: Engineering Design

A. Defining and Delimiting and Engineering Problems
B. Developing Possible Solutions
C. Optimizing the Solution Design

ETS2: Links Among Engineering, Technology, Science, and Society

A. Interdependence of Science, Technology, Engineering, and Math (STEM)
B. Influence of Engineering, Technology, and Science on Society and the Natural World

ETS3: Applications of Science

A. Nature of Science Components
B. Theory Development and Revision
C. Science Practices: Utilization in Developing and Conducting Original Scientific Research
D. Practice of Peer Review

Crosscutting Concepts

These are concepts that permeate all science and show an interdependent connection among the sciences differentiated from grades K-12. Tennessee state science standards have explicitly designed the standard progression to include these crosscutting concepts:

- Pattern observation and explanation
- Cause and effect relationships that can be explained through a mechanism
- Scale, proportion, and quantity that integrate measurement and precision of language
- Systems and system models with defined boundaries that can be investigated and characterized by the next three concepts
- Energy and matter conservation through transformations that flow or cycle into, out of, or within a system
- Structure and function of systems and their parts
- Stability and change of systems

Science and Engineering Practices

The science and engineering practices are used as a means to learn science by doing science, thus combining knowledge with skill. The goal is to allow students to discover how scientific knowledge is produced and how engineering solutions are developed. The following practices should not be taught in isolation or as a separate unit, but rather differentiated at each grade level from K-12 and integrated into all core ideas employed throughout the school year. These are not to be taught in isolation but are embedded throughout the language of the standards.

- Asking questions (for science) and defining problems (for engineering) to determine what is known, what has yet to be satisfactorily explained, and what problems need to be solved.

- Developing and using models to develop explanations for phenomena, to go beyond the observable and make predictions or to test designs.
- Planning and carrying out controlled investigations to collect data that is used to test existing theories and explanations, revise and develop new theories and explanations, or assess the effectiveness, efficiency, and durability of designs under various conditions.
- Analyzing and interpreting data with appropriate data presentation (graph, table, statistics, etc.), identifying sources of error and the degree of certainty. Data analysis is used to derive meaning or evaluate solutions.
- Using mathematics and computational thinking as tools to represent variables and their relationships in models, simulations, and data analysis in order to make and test predictions.
- Constructing explanations and designing solutions to explain phenomena or solve problems.
- Engaging in argument from evidence to identify strengths and weaknesses in a line of reasoning, to identify best explanations, to resolve problems, and to identify best solutions.
- Obtaining, evaluating, and communicating information from scientific texts in order to derive meaning, evaluate validity, and integrate information.

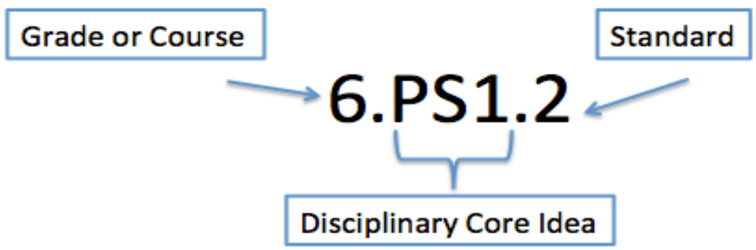
Engineering Technology and Science Practice Standards (ETS)

Technology is embedded within the writing of the engineering standards. While engineering is a disciplinary core idea, it will also be taught within the context of other disciplinary core ideas. Stakeholders recognize the importance of design and innovative solutions that can be related to the application of scientific knowledge in our society, thereby further preparing a science, technology, engineering, and math (STEM) literate student for their college and career. STEM integration has been supported both as a stand-alone disciplinary core idea.

Structure of the Standards

The organization and structure of this standards document includes:

- **Grade Level/Course Overview:** An overview that describes that specific content and themes for each grade level or high school course.
- **Disciplinary Core Idea:** Scientific and foundational ideas that permeate all grades and connect common themes that bridge scientific disciplines.
- **Standard:** Statements of what students can do to demonstrate knowledge of the conceptual understanding. Each performance indicator includes a specific science and engineering practice paired with the content knowledge and skills that students should demonstrate to meet the grade level or high school course standards.



Elementary School Progression

The elementary science progression is designed to capture the curiosity of children through relevant scientific content. Children are born investigators and have surprisingly sophisticated ways of thinking about the world. Engaging a young scientist with the practices and discipline of science is imperative in all grades but essential in grades K-5. It is important to build progressively more complex explanations of science and natural phenomena. Children form mental models of what science is at a young age. These mental models can lead to misconceptions, if not confronted early and addressed with a scaffolding of science content. It is the goal of elementary science to give background knowledge and age appropriate interaction with science as a platform to launch into deeper scientific thinking in grades 6-12.

Middle School Progression

Integrated science is a core focus within the middle school grades, and therefore, DCIs and their components are mixed heterogeneously throughout grades 6-8. Middle school science has a standards shift that more appropriately reflects content with crosscutting concepts as opposed to concentrating on topics as discrete notions in isolation. This is accomplished both within and through the grade levels by scaffolding core ideas with fluidity, relevance, and relatedness. For example, the physical science DCIs introduced in seventh grade are necessary for understanding the life science DCIs in seventh grade. This in turn supports the more advanced life science DCIs in eighth grade. Middle school teachers recognize that learning develops over time, and learning progressions must follow a clear path with appropriate grade-level expectations.

For Physical Sciences (PS) starting in sixth grade, students utilize the science and engineering practices to engage in ideas of energy. Energy as a physical science concept integrates throughout ecosystems (e.g., populations food webs) and Earth and space science (e.g., weather and ocean circulation), which in turn impacts ecoregions of the world. Seventh grade improves upon this understanding by applying energy to states of matter and reactions. Fundamental concepts regarding matter allow students to understand reactions such as photosynthesis, respiration, and biogeochemical cycles in greater depth. Additionally, introducing matter facilitates life sciences from a molecular level beyond organismal levels. Biomolecules introduce a molecular approach through heredity. Eighth grade builds upon these concepts further to examine forces and motion and their relatedness to energy and matter. Physical forces integrate through Earth and space science (e.g., plate tectonics, rock cycle), driving long term geological changes that impact ecosystems and their inhabitants. The understanding of heredity in seventh grade allows students to make connections through natural selection, driven by the physical forces of earth systems in eighth grade.

For Life Sciences (LS), students model ecosystems and make connections between populations of organisms, while focusing on the crosscutting concept of energy. Energy drives ecosystems and populations within those ecosystems. The energy that drives weather and ocean circulation also impacts ecosystems (e.g., biomes). Seventh grade students have a foundation of energy from sixth grade and therefore are able to examine how a single species of those ecosystems is built from the molecule up and can pass on traits through the process of reproduction. Eighth grade utilizes understandings from ecosystems and heredity to examine changes in an ecosystem and species over time as it relates to physical forces that drive Earth systems.

For Earth and Space Sciences (ESS), sixth grade students examine weather and climate with a focus on energy and ecosystems. Seventh grade looks through the lens of matter and energy to trace biogeochemical cycling, particularly carbon, and scaffolds from climate in sixth grade to climate change. Eighth grade employs crosscutting concepts of cycles and patterns to focus on biogeology, especially the rock cycle and plate tectonics. Eighth grade students apply understanding of forces and motion to an examination of our own planetary processes and those of other celestial objects.
Grade level articulation of DCIs is important for progression; however, continuity and flow is critical for integrated science within a grade level as well. Sixth grade students apply energy and energy transfer to food webs and population sizes in ecosystems, heating and convective processes in weather, and climate, natural resources, and energy production, which can then be linked with ecosystems. Seventh grade students can more appropriately understand how matter and reactions determine cellular structures and functions, like photosynthesis and aerobic cellular respiration or the inheritance of traits, once they have a background in matter and reactions. The foundation of photosynthesis and respiration at the cellular level helps students make concrete connections to biogeochemical cycling, particularly the carbon/oxygen cycle, combustion, and changes in atmospheric conditions. Eighth grade students use understanding of forces and motion to examine multiple concepts such as the expanding universe, biogeological processes such as the rock cycle and plate tectonics, and the impacts of these processes to ecosystem change and species within those ecosystems.

High School Progression

When students enter high school, they will have experienced a broad, interdisciplinary science education as they progressed through grades K-8. The notions defined in the K-8 science standards will frame this experience. The high school progression will continue on this path and further embed themes of mathematics and English language arts into the science standards. The progression of science education in high school acknowledges and complements the cognitive development of the student.

DCIs are presented in course offerings in the Physical Sciences, Life Sciences, and Earth and Space Sciences. There are specific science standards for biology, human anatomy and physiology, physical science, chemistry, physics, and Earth and space science. A student's progress through high school science courses is particularly parallel to his or her mathematical progress. As his or her mathematical experience and acumen develops, so too will science expectations and experiences.

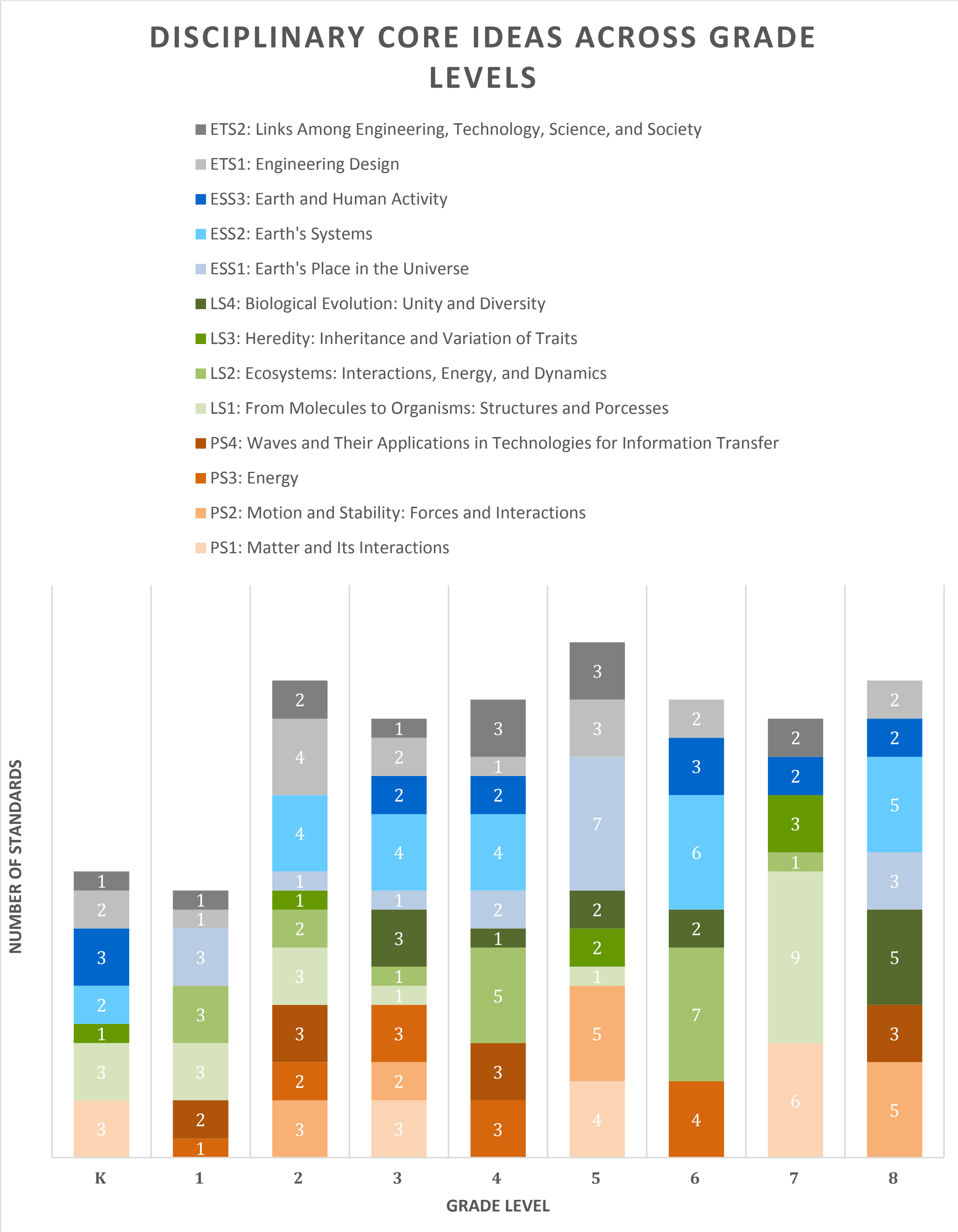
Grade Level Overviews

The addition of grade level overviews outlines the core ideas for a particular grade/course. A table of core ideas has been entered and color-coded so that within-grade/course crosscutting concepts and practices may be observed in addition to vertical alignment and sequencing. Bolded items are taught within a course/grade, while lightly shaded items are not.

Shifts in Sequence

Grade Level	Previous Standards (2009)	Current Standards (2018)
K-5	There are 14 themes in each grade level.	Fewer themes are covered and focus on a progression that builds stronger background knowledge and science experience through embedded practice of science and technology.
6-8	There are 14 themes covered by the end of eighth grade; they are heterogeneously grouped in each grade level, but there are no connecting strands or overarching concepts.	Middle grades are heterogeneously grouped in science, but strong crosscutting concepts attach scientific ideas, producing a more fluid progression and deeper knowledge of content.
High School – Life Sciences *1 biology credit required for graduation*	Overall, life science standards are often repetitive within and between courses. Many standards lack depth, while others are evasive. The sequence requires students to take Biology I for graduation, with additional options for Biology II, Human Anatomy and Physiology, Ecology, and Environmental Science, among other elective courses.	A sequence of streamlined DCIs from grades K-8 seeks to better vertically align with the high school offerings. All course standards have a clear focus and application as determined by the aforementioned vision.
High School – Physical Sciences *1 physics or chemistry credit required for graduation*	Standards are articulated for 13 courses including life sciences, physical sciences, and Earth sciences. Sequencing requires biology and chemistry and many elective lab science choices to achieve state requirements of 3 lab science credits.	All state science course standards have been reviewed and rewritten to conform to concepts addressed in the frameworks.

1 additional lab science choice of PS, LS, or ES



DISCIPLINARY CORE IDEAS ACROSS GRADE LEVELS
ETS2: Links Among Engineering, Technology, Science, and Society
ETS1: Engineering Design
ESS3: Earth and Human Activity
ESS2: Earth's Systems
ESS1: Earth's Place in the Universe
LS4: Biological Evolution: Unity and Diversity
LS3: Heredity: Inheritance and Variation of Traits
LS2: Ecosystems: Interactions, Energy, and Dynamics
LS1: From Molecules to Organisms: Structures and Porcesses
PS4: Waves and Their Applications in Technologies for Information Transfer
PS3: Energy
PS2: Motion and Stability: Forces and Interactions
PS1: Matter and Its Interactions
NUMBER OF STANDARDS
K
1
2
3
4
5
6
7
8
GRADE LEVEL

DCI		Grade levels
Physical Science (PS)	PS1: Matter and its Interactions	K>3>5>7
	PS2: Motion and Stability: Forces and interactions	2>3>5>8
	PS3: Energy	1>2>3>4>6
	PS4: Waves and their applications in technologies for information transfer	1>2>4>8
Life Science (LS)	LS1: From molecules to organisms: Structure and Process	K>1>2>3>5>7
	LS2: Ecosystems: Interactions, energy and dynamics	1>2>3>4>6>7
	LS3: Heredity: Inheritance and variation of traits	K>2>5>7
	LS4: Biological Change: Unity and Diversity	3>4>5>6>8
Earth and Space Science (ESS)	ESS1: Earth's place in the Universe	1>2>3>4>5>8
	ESS2: Earth's Systems	K>2>3>4>6>8
	ESS3: Earth and Human Activity	K>3>4>6>7>8
Engineering, Technology, and Applications of Science (ETS)	ETS1: Engineering Design	K>1>2>3>4>5>6>8
	ETS2: Links Among Engineering, Technology, and Science on Society and the Natural World	K>1>2>3>4>5>7

Recommended Mathematical and Literacy Skills for Science Proficiency

As a student's mathematical skills and experiences expand, so does his or her capacity to analyze, describe, and predict a broader range of natural phenomena. The science standards will explicitly develop along with and parallel to the Tennessee mathematical standards for grades K-12.

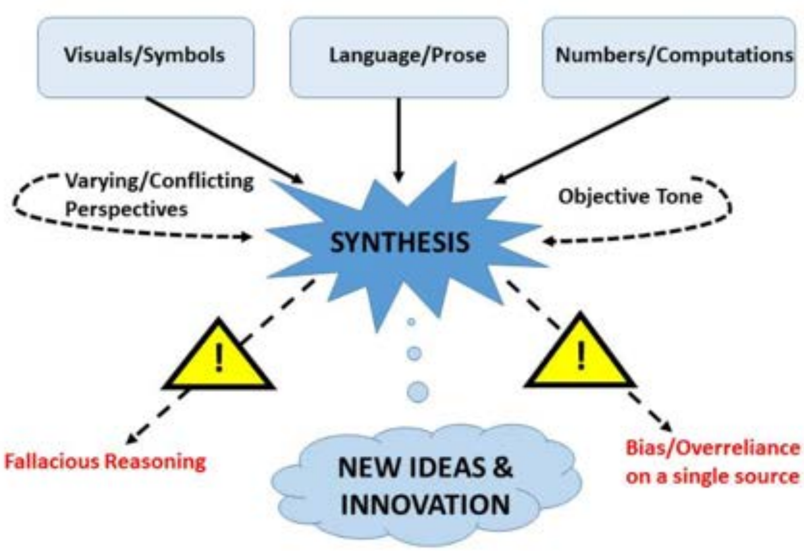
Effective communication within a scientific context requires students to apply literacy skills in reading, vocabulary, speaking and listening, and writing. Scientific information is presented in many formats with various tones and perspectives. Students must process and synthesize information effectively to generate new conclusions and ideas while avoiding the pitfalls of fallacious reasoning and bias.

Reading: Students should have regular practice with complex text and academic language beyond the textbook, such as scientific journals, popular magazines, and vetted Internet sites. Scientifically literate students should be able to read and decode information presented in multiple formats, including charts, tables, info graphics, and flowcharts.

Vocabulary: Understanding and applying scientific vocabulary correctly is essential to science literacy. Scientifically literate students appropriately link technical and academic vocabulary words in the communication of scientific phenomena.

Speaking and Listening: Scientifically literate students listen critically and engage in productive discussions surrounding a critique of scientific evidence and the validity of resulting conclusions.

Writing: Writing in a science classroom does not mimic that of writing in an English language arts classroom. Students in early grades should begin to employ technical writing skills to strengthen sequencing skills, as done through the writing of procedures. In high school, students should be able to write a report complete with introduction, methods, results, analysis, and conclusion.



Students should be experiencing science content in a way that incorporates literacy to help build the foundational skills of observation, explanation, and argumentation.

Students' Responsibilities:

- Use scientifically focused speaking and listening skills on a daily basis.
- Interact with data presented in multiple ways:
  - Visually through charts, graphs, infographics, and traditional text
  - Auditorily through podcasts and multimedia production
  - Tactically through the use of traditional lab experiences and non-traditional lab simulations
- Present data and findings in multiple ways
- Build an appropriate scientific academic vocabulary

Teachers' Responsibilities:

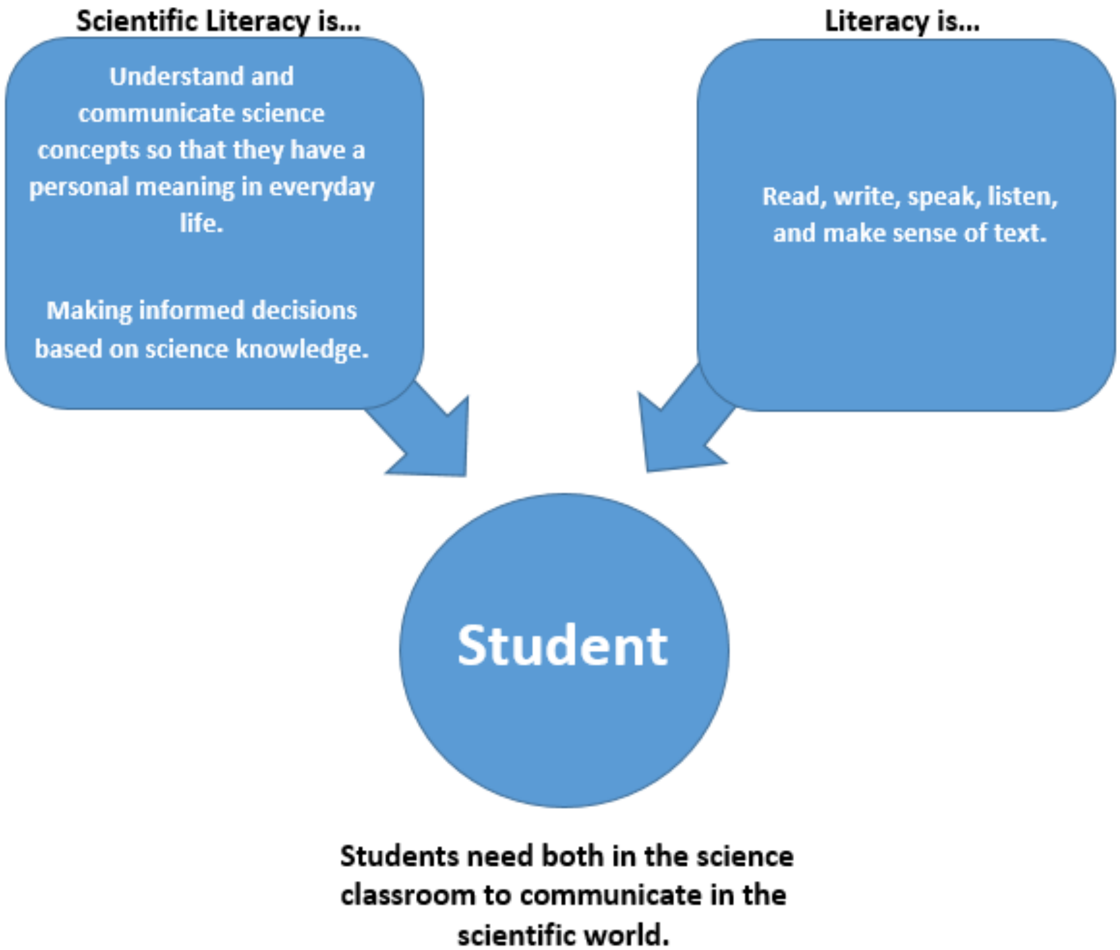
- Encourage the use of science and engineering practices to guide the development of literacy skills in science
- Provide a balance of appropriate sources beyond the textbook
- Provide opportunities for students to engage one another in critical discussion and argument surrounding specific content as well as data presentation
- Give consistent feedback on student writing and presentation
- Guide student research and access to content specific information from articles and journals while intentionally focusing on gaps in academic vocabulary

Leaders' Responsibilities:

- Support teachers in text selection, developing writing experiences, and encouraging content level collaboration as well as collaboration with English/Language Arts teachers

- Support teachers in choosing classroom activities that provide opportunities for discovery, inquiry, and the communication of scientific phenomena in multiple forms

Scientific Literacy vs. Literacy



KINDERGARTEN: GRADE OVERVIEW

The academic standards for Kindergarten establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of scientific practical experiences. The academic standards for science in Kindergarten are based on research and the National Research Council's *Framework for K-12 Science Education*.

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of Kindergarten. Disciplinary core ideas for Kindergarten include:

Kindergarten			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications in Technologies for Information Transfer	Biological Change: Unity and Diversity		

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Kindergarten standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each disciplinary core idea (PS, LS, ESS) to provide students with a well-rounded education in science.

By the end of Kindergarten, students are introduced to matter and its interactions by constructing experiments with solids and liquids. Students make connections and use senses by classifying observable properties of matter and classifying living and nonliving things. Throughout the year, Kindergarten students use their observation skills to identify weather patterns and seasons. Students also use observations and evidence to identify the relationship between earth and human activities.

KINDERGARTEN: ACADEMIC STANDARDS

K.PS1: Matter and Its Interactions

1) Plan and conduct an investigation to describe and classify different kinds of materials including wood, plastic, metal, cloth, and paper by their observable properties (color, texture, hardness, and flexibility) and whether they are natural or human-made.

2) Conduct investigations to understand that matter can exist in different states (solid and liquid) and has properties that can be observed and tested.

3) Construct an evidence-based account of how an object made of a small set of pieces (blocks, snap cubes) can be disassembled and made into a new object.

K.LS1: From Molecules to Organisms: Structures and Processes

1) Use information from observations to identify differences between plants and animals (locomotion, obtainment of food, and take in air/gasses).

2) Recognize differences between living organisms and non-living materials and sort them into groups by observable physical attributes.

3) Explain how humans use their five senses in making scientific findings.

K.LS3.1: Heredity: Inheritance and Variation of Traits

1) Make observations to describe that young plants and animals resemble their parents.

K.ESS2: Earth's Systems

1) Analyze and interpret weather data (precipitation, wind, temperature, cloud cover) to describe weather patterns that occur over time (hourly, daily) using simple graphs, pictorial weather symbols, and tools (thermometer, rain gauge).

2) Develop and use models to predict weather and identify patterns in spring, summer, autumn, and winter.

K.ESS3: Earth and Human Activity

1) Use a model to represent the relationship between the basic needs (shelter, food, water) of different plants and animals (including humans) and the places they live.

2) Explain the purpose of weather forecasting to prepare for, and respond to, severe weather in Tennessee.

3) Communicate solutions that will reduce the impact from humans on land, water, air, and other living things in the local environment.

K.ETS1: Engineering Design

1) Ask and answer questions about the scientific world and gather information using the senses.

2) Describe objects accurately by drawing and/or labeling pictures.

K.ETS2: Links Among Engineering, Technology, Science, and Society

1) Use appropriate tools (magnifying glass, rain gauge, basic balance scale) to make observations and answer testable scientific questions.

2) Apply engineering design and creative thinking to solve practical problems.

FIRST GRADE: OVERVIEW

The academic standards for first grade establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of scientific practical experiences. The academic standards for science in first grade are based on research and the National Research Council's *Framework for K-12 Science Education*.

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of first grade. Science and engineering practices are not to be taught in isolation but within the science content. Disciplinary core ideas for first grade include:

First Grade			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications	Biological Change: Unity and Diversity		

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The first grade standards have been constructed by explicitly integrating practices and crosscutting concepts,

iteratively and in combination, within each disciplinary core idea (PS, LS, ESS) to provide students with a well-rounded education in science.

By the end of first grade, students encounter energy of sunlight and the effects on the earth's surface. First graders experiment with light investigations to determine how different materials interact with light. Investigating plants, parts of the plant, life cycle of plants, and interdependence of plants and the surrounding environment is an essential building block toward more complex content. Students learn about patterns in the day and night sky, that the telescope and naked eye can identify celestial objects in the sky, and the patterns of earth, moon, and sun.

FIRST GRADE: ACADEMIC STANDARDS

1.PS3: Energy

1) Make observations to determine how sunlight warms Earth's surfaces (sand, soil, rocks, and water).

1.PS4: Waves and Their Application in Technologies for Information Transfer

1) Use a model to describe how light is required to make objects visible. Summarize how Illumination could be from an external light source or by an object giving off its own light.

2) Determine the effect of placing objects made with different materials (transparent, translucent, opaque, and reflective) in the path of a beam of light.

1.LS1: From Molecules to Organisms: Structures and Processes

1) Recognize the structure of plants (roots, stems, leaves, flowers, fruits) and describe the function of the parts (taking in water and air, producing food, making new plants).

2) Illustrate and summarize the life cycle of plants.

3) Analyze and interpret data from observations to describe how changes in the environment cause plants to respond in different ways.

1.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Conduct an experiment to show how plants depend on air, water, minerals from soil, and light to grow and thrive.

2) Obtain and communicate information to classify plants by where they grow (water, land) and the plant's physical characteristics.

3) Recognize how plants depend on their surroundings and other living things to meet their needs in the places they live.

1.ESS1: Earth's Place in the Universe

1) Use observations or models of the sun, moon, and stars to describe patterns that can be predicted.

2) Observe natural objects in the sky that can be seen from Earth with the naked eye and recognize that a telescope, used as a tool, can provide greater detail of objects in the sky.

3) Analyze data to predict patterns between sunrise and sunset, and the change of seasons.

1.ETS1: Engineering Design

1) Solve scientific problems by asking testable questions, making short-term and long-term observations, and gathering information.

1.ETS2: Links Among Engineering, Technology, Science, and Society

1) Use appropriate tools (magnifying glass, basic balance scale) to make observations and answer testable scientific questions.

2) Apply engineering design and creative thinking to solve practical problems.

SECOND GRADE: OVERVIEW

The academic standards for second grade establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of scientific practical experiences. The academic standards for science in second grade are based on research and the National Research Council's *Framework for K-12 Science Education*.

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of second grade. Disciplinary core ideas for second grade include:

Second Grade			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications in Technologies for Information Transfer	Biological Change: Unity and Diversity		

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The second grade standards have been constructed by explicitly integrating practices and crosscutting concepts,

iteratively and in combination, within each disciplinary core idea (PS, LS, ESS) to provide students with a well-rounded education in science.

By the end of second grade, students discover forces and interactions by experimenting with different strengths and directions of pushing and pulling and designing experiments to discover the relationship between speed and direction of an object using force. Students discover waves and the transfer of information by experimenting with light and sound energy. Second grade students learn life cycles and classifications of animals and adaptations for survival. Students use textual evidence to cite ways that the earth is changing and understand the changing surface of the Earth.

SECOND GRADE: ACADEMIC STANDARDS

2.PS2: Motion and Stability: Forces and Interactions

1) Analyze the push or the pull that occurs when objects collide or are connected.

2) Evaluate the effects of different strengths and directions of a push or a pull on the motion of an object.

3) Recognize the effect of multiple pushes and pulls on an object's movement or non-movement.

2.PS3: Energy

1) Demonstrate how a stronger push or pull makes things go faster and how faster speeds during a collision can cause a bigger change in the shape of the colliding objects.

2) Make observations and conduct experiments to provide evidence that friction produces heat and reduces or increases the motion of an object.

2.PS4: Waves and Their Applications in Technologies for Information Transfer

1) Plan and conduct investigations to demonstrate the cause and effect relationship between vibrating materials (tuning forks, water, bells) and sound.

2) Use tools and materials to design and build a device to understand that light and sound travel in waves and can send signals over a distance.

3) Observe and demonstrate that waves move in regular patterns of motion by disturbing the surface of shallow and deep water.

2.LS1: From Molecules to Organisms: Structures and Processes

1) Use evidence and observations to explain that many animals use their body parts and senses in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water, and air.

2) Obtain and communicate information to classify animals (vertebrates-mammals, birds, amphibians, reptiles, fish, invertebrates-insects) based on their physical characteristics.

3) Use simple graphical representations to show that species have unique and diverse life cycles.

2.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Develop and use models to compare how animals depend on their surroundings and other living things to meet their needs in the places they live.

2) Predict what happens to animals when the environment changes (temperature, cutting down trees, wildfires, pollution, salinity, drought, land preservation).

2.LS3: Heredity: Inheritance and Variation of Traits

1) Use evidence to explain that living things have physical traits inherited from parents and that variations of these traits exist in groups of similar organisms.

2.ESS1: Earth's Place in the Universe

1) Recognize that some of Earth's natural processes are cyclical, while others have a beginning and an end. Some events happen quickly, while others occur slowly over time.

2.ESS2: Earth's Systems

1) Compare the effectiveness of multiple solutions designed to slow or prevent wind or water from changing the shape of the land.

2) Observe and analyze how blowing wind and flowing water can move Earth materials (soil, rocks) from one place to another, changing the shape of a landform and affecting the habitats of living things.

3) Compare simple maps of different land areas to observe the shapes and kinds of land (rock, soil, sand) and water (river, stream, lake, pond).

4) Use information obtained from reliable sources to explain that water is found in the ocean, rivers, streams, lakes, and ponds, and may be solid or liquid.

2.ETS1: Engineering Design

1) Define a simple problem that can be solved through the development of a new or improved object or tool by asking questions, making observations, and gather accurate information about a situation people want to change.

2) Develop a simple sketch, drawing, or physical model that communicates solutions to others.

3) Recognize that to solve a problem, one may need to break the problem into parts, address each part, and then bring the parts back together

4) Compare and contrast solutions to a design problem by using evidence to point out strengths and weaknesses of the design.

2.ETS2: Links Among Engineering, Technology, Science, and Society

1) Use appropriate tools to make observations, record data, and refine design ideas.

2) Predict and explain how human life and the natural world would be different without current technologies.

THIRD GRADE: OVERVIEW

The academic standards for third grade establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of scientific practical experiences. The academic standards for science in third grade are based on research and the National Research Council's *Framework for K-12 Science Education*.

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of third grade. Disciplinary core ideas for third grade include:

Third Grade			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications in Technologies for Information Transfer	Biological Change: Unity and Diversity		

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The third grade standards have been constructed by explicitly integrating practices and crosscutting concepts,

iteratively and in combination, within each disciplinary core idea (PS, LS, ESS) to provide students with a well-rounded education in science.

By the end of third grade, students analyze internal and external structures that function supporting survival along with how they adapt to their environment. Students investigate the cause and effect relationships of magnets. Students experiment with static electricity and design a device that converts energy from one form to another. Students investigate and categorize the physical properties of planets. Students synthesize different forms of data to predict and learn about weather patterns, climates, different forms of water, and how different types of clouds all contribute to weather. Students learn about natural hazards and design and test solutions to minimize the impact of these.

THIRD GRADE: ACADEMIC STANDARDS

3.PS1: Matter and Its Interactions

1) Describe the properties of solids, liquids, and gases and identify that matter is made up of particles too small to be seen.

2) Differentiate between changes caused by heating or cooling that can be reversed and that cannot.

3) Describe and compare the physical properties of matter including color, texture, shape, length, mass, temperature, volume, state, hardness, and flexibility.

3.PS2: Motion and Stability: Forces and Interactions

1) Explain the cause and effect relationship of magnets.

2) Solve a problem by applying the use of the interactions between two magnets.

3.PS3: Energy

1) Recognize that energy is present when objects move; describe the effects of energy transfer from one object to another.

2) Apply scientific ideas to design, test, and refine a device that converts electrical energy to another form of energy, using open or closed simple circuits.

3) Evaluate how magnets cause changes in the motion and position of objects, even when the objects are not touching the magnet.

3.LS1: From Molecules to Organisms: Structures and Processes

1) Analyze the internal and external structures that aquatic and land animals and plants have to support survival, growth, behavior, and reproduction.

3.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Construct an argument to explain why some animals benefit from forming groups.

3.LS4: Biological Change: Unity and Diversity

1) Explain the cause and effect relationship between a naturally changing environment and an organism's ability to survive.

2) Infer that plant and animal adaptations help them survive in land and aquatic biomes.

3) Explain how changes to an environment's biodiversity influence human resources.

3.ESS1: Earth’s Place in the Universe

1) Use data to categorize the planets in the solar system as inner or outer planets according to their physical properties.

3.ESS2: Earth’s Systems

1) Explain the cycle of water on Earth.

2) Associate major cloud types (cumulus, cumulonimbus, cirrus, stratus, nimbostratus) with weather conditions.

3) Use tables, graphs, and tools to describe precipitation, temperature, and wind (direction and speed) to determine local weather and climate.

4) Incorporate weather data to describe major climates (polar, temperate, tropical) in different regions of the world.

3.ESS3: Earth and Human Activity

1) Explain how natural hazards (fires, landslides, earthquakes, volcanic eruptions, floods) impact humans and the environment.

2) Design solutions to reduce the impact of natural hazards (fires, landslides, earthquakes, volcanic eruptions, floods) on the environment.

3.ETS1: Engineering Design

1) Design a solution to a real-world problem that includes specified criteria for constraints.

2) Apply evidence or research to support a design solution.

3.ETS2: Links Among Engineering, Technology, Science, and Society

1) Identify and demonstrate how technology can be used for different purposes.

FOURTH GRADE: OVERVIEW

The academic standards for fourth grade establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of scientific practical experiences. The academic standards for science in fourth grade are based on research and the National Research Council's *Framework for K-12 Science Education*.

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of fourth grade. Disciplinary core ideas for fourth grade include:

Fourth Grade			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications in Technologies for Information Transfer	Biological Change: Unity and Diversity		

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The fourth grade standards have been constructed by explicitly integrating practices and crosscutting concepts,

iteratively and in combination, within each disciplinary core idea (PS, LS, ESS) to provide students with a well-rounded education in science.

By the end of fourth grade, students develop an understanding how plants, animals, and nonliving things in an ecosystem interact with each other. They analyze temporary and permanent changes caused by weather and living things on Earth's land and water, and they investigate how the placements of certain landforms create a predictable pattern. Students examine various types of energy transfer, including sound, light, heat, and electric currents, and model how energy transforms with added speed or in a collision. They create models to explain how waves travel and how waves of light become visible to humans.

FOURTH GRADE: ACADEMIC STANDARDS

4.PS3: Energy

1) Use evidence to explain the cause and effect relationship between the speed of an object and the energy of an object.

2) Observe and explain the relationship between potential energy and kinetic energy.

3) Describe how stored energy can be converted into another form for practical use.

4.PS4: Waves and their Application in Technologies for Information Transfer

1) Use a model of a simple wave to explain regular patterns of amplitude, wavelength, and direction.

2) Describe how the colors of available light sources and the bending of light waves determine what we see.

3) Investigate how lenses and digital devices like computers or cell phones use waves to enhance human senses.

4.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Support an argument with evidence that plants get the materials they need for growth and reproduction chiefly through a process in which they use carbon dioxide from the air, water, and energy from the sun to produce sugars, plant materials, and waste (oxygen); and that this process is called photosynthesis.

2) Develop models of terrestrial and aquatic food chains to describe the movement of energy among producers, herbivores, carnivores, omnivores, and decomposers.

3) Using information about the roles of organisms (producers, consumers, decomposers), evaluate how those roles in food chains are interconnected in a food web, and communicate how the organisms are continuously able to meet their needs in a stable food web.

4) Develop and use models to determine the effects of introducing a species to, or removing a species from, an ecosystem and how either one can damage the balance of an ecosystem.

5) Analyze and interpret data about changes (land characteristics, water distribution, temperature, food, and other organisms) in the environment and describe what mechanisms organisms can use to affect their ability to survive and reproduce.

4.LS4: Biological Change: Unity and Diversity

1) Obtain information about what a fossil is and ways a fossil can provide information about the past.

4.ESS1: Earth's Place in the Universe

1) Generate and support a claim with evidence that over long periods of time, erosion (weathering and transportation) and deposition have changed landscapes and created new landforms.

2) Use a model to explain how the orbit of the Earth and sun cause observable patterns: a. day and night; b. changes in length and direction of shadows over a day.

4.ESS2: Earth's Systems

1) Collect and analyze data from observations to provide evidence that rocks, soils, and sediments are broken into smaller pieces through mechanical weathering (frost wedging, abrasion, tree root wedging) and are transported by water, ice, wind, gravity, and vegetation.

2) Interpret maps to determine that the location of mountain ranges, deep ocean trenches, volcanoes, and earthquakes occur in patterns.

3) Provide examples to support the claim that organisms affect the physical characteristics of their regions.

4) Analyze and interpret data on the four layers of the Earth, including thickness, composition, and physical states of these layers.

4.ESS3: Earth and Human Activity

1) Obtain and combine information to describe that energy and fuels are derived from natural resources and that some energy and fuel sources are renewable (sunlight, wind, water) and some are not (fossil fuels, minerals).

2) Create an argument, using evidence from research, that human activity (farming, mining, building) can affect the land and ocean in positive and/or negative ways.

4.ETS1: Engineering Design

1) Categorize the effectiveness of design solutions by comparing them to specified criteria for constraints.

4.ETS2: Links Among Engineering, Technology, Science, and Society

1) Use appropriate tools and measurements to build a model.

2) Determine the effectiveness of multiple solutions to a design problem given the criteria and the constraints.

3) Explain how engineers have improved existing technologies to increase their benefits, to decrease known risks, and to meet societal demands (artificial limbs, seatbelts, cell phones).

FIFTH GRADE: OVERVIEW

The academic standards for fifth grade establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of scientific practical experiences. The academic standards for science in fifth grade are based on research and the National Research Council's *Framework for K-12 Science Education*.

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of fifth grade. Disciplinary core ideas for fifth grade include:

Fifth Grade			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications in Technologies for Information Transfer	Biological Change: Unity and Diversity		

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The fifth grade standards have been constructed by explicitly integrating practices and crosscutting concepts,

iteratively and in combination, within each disciplinary core idea (PS, LS, ESS) to provide students with a well-rounded education in science.

By the end of fifth grade, students explore Earth's materials and systems. They use models and data to investigate factors that affect climate and the cycling of water. Students investigate the distribution and role of the Earth's water. Students should explain the impact on earth's resources and climate when analyzing relationships between humans and the environment. Students examine inherited traits and variations and how these variations lead to species survival. In physical science, they learn about physical properties of matter and chemical reactions by discovering matter is not destroyed, only changed. Investigating forces and motion, students focus on balanced and unbalanced forces and explore patterns of change in physical systems along with gravitational forces.

FIFTH GRADE: ACADEMIC STANDARDS

5.PS1: Matter and Its Interactions

1) Analyze and interpret data from observations and measurements of the physical properties of matter to explain phase changes between a solid, liquid, or gas.

2) Analyze and interpret data to show that the amount of matter is conserved even when it changes form, including transitions where matter seems to vanish.

3) Design a process to measure how different variables (temperature, particle size, stirring) affect the rate of dissolving solids into liquids.

4) Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties.

5.PS2: Motion and Stability: Forces and Interactions

1) Test the effects of balanced and unbalanced forces on the speed and direction of motion of objects.

2) Make observations and measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

3) Use evidence to support that the gravitational force exerted by Earth on objects is directed toward the Earth's center.

4) Explain the cause and effect relationship of two factors (mass and distance) that affect gravity.

5) Explain how forces can create patterns within a system (moving in one direction, shifting back and forth, or moving in cycles), and describe conditions that affect how fast or slowly these patterns occur.

5.LS1: From Molecules to Organisms: Structures and Processes

1) Compare and contrast animal responses that are instinctual versus those that that are gathered through the senses, processed, and stored as memories to guide their actions.

5.LS3: Heredity: Inheritance and Variation of Traits

1) Distinguish between inherited characteristics and those characteristics that result from a direct interaction with the environment. Apply this concept by giving examples of characteristics of living organisms that are influenced by both inheritance and the environment.

2) Provide evidence and analyze data that plants and animals have traits inherited from parents and that variations of these traits exist in a group of similar organisms.

5.LS4: Biological Change: Unity and Diversity

1) Analyze and interpret data from fossils to describe types of organisms and their environments that existed long ago. Compare similarities and differences of those to living organisms and their environments. Recognize that most kinds of animals (and plants) that once lived on Earth are now extinct.

2) Use evidence to construct an explanation for how variations in characteristics among individuals within the same species may provide advantages to these individuals in their survival and reproduction.

5.ESS1: Earth's Place in the Universe

1) Explain that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from the Earth.

2) Research and explain the position of the Earth and the solar system within the Milky Way galaxy, and compare the size and shape of the Milky Way to other galaxies in the universe.

3) Use data to categorize different bodies in our solar system including moons, asteroids, comets, and meteoroids according to their physical properties and motion.

4) Explain the cause and effect relationship between the positions of the sun, earth, and moon and resulting eclipses, position of constellations, and appearance of the moon.

5) Relate the tilt of the Earth's axis, as it revolves around the sun, to the varying intensities of sunlight at different latitudes. Evaluate how this causes changes in day-lengths and seasons.

6) Use tools to describe how stars and constellations appear to move from the Earth's perspective throughout the seasons.

7) Use evidence from the presence and location of fossils to determine the order in which rock strata were formed.

5.ETS1: Engineering Design

1) Research, test, re-test, and communicate a design to solve a problem.

2) Plan and carry out tests on one or more elements of a prototype in which variables are controlled and failure points are considered to identify which elements need to be improved. Apply the results of tests to redesign the prototype.

3) Describe how failure provides valuable information toward finding a solution.

5.ETS2: Links Among Engineering, Technology, Science, and Society

1) Use appropriate measuring tools, simple hand tools, and fasteners to construct a prototype of a new or improved technology.

2) Describe how human beings have made tools and machines (X-ray cameras, microscopes, satellites, computers) to observe and do things that they could not otherwise sense or do at all, or as quickly or efficiently.

3) Identify how scientific discoveries lead to new and improved technologies.

SIXTH GRADE: OVERVIEW

The academic standards for sixth grade establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of scientific practical experiences. The academic standards for science in sixth grade are based on research and the National Research Council's *Framework for K-12 Science Education.*

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of sixth grade. Disciplinary core ideas for sixth grade include:

Sixth Grade			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications in Technologies for Information Transfer	Biological Change: Unity and Diversity		

The standards incorporated into this grade have been streamlined for the students' K-12 coherent experience for a diversity of learners. The theme for sixth grade science is how energy, found in multiple systems and scales, is driving ecosystems (populations, food chains/webs), Earth's natural resources, and Earth processes (oceans, weather, and climate). In turn, oceans, weather, and climate help determine characteristics of ecosystems. A focus on science literacy is placed through the use of the science and engineering practices. Often times, students are required to gather information from reliable sources to construct evidenced-based arguments (e.g., 6.LS2.3). Finally, STEM integration is supported both as a stand-alone disciplinary core idea.

By the end of sixth grade, it is expected that students should be able to demonstrate the skills and content knowledge emphasized in the following standards in preparation for future learning in science and its practice.

SIXTH GRADE: ACADEMIC STANDARDS

6.PS3: Energy

1) Analyze the properties and compare sources of kinetic, elastic potential, gravitational potential, electric potential, chemical, and thermal energy.

2) Construct a scientific explanation of the transformations between potential and kinetic energy.

3) Analyze and interpret data to show the relationship between kinetic energy and the mass of an object in motion and its speed.

4) Conduct an investigation to demonstrate the way that heat (thermal energy) moves among objects through radiation, conduction, or convection.

6.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Evaluate and communicate the impact of environmental variables on population size.

2) Determine the impact of competitive, symbiotic, and predatory interactions in an ecosystem.

3) Draw conclusions about the transfer of energy through a food web and energy pyramid in an ecosystem.

4) Using evidence from climate data, draw conclusions about the patterns of abiotic and biotic factors in different biomes, specifically the tundra, taiga, deciduous forest, desert, grasslands, rainforest, marine, and freshwater ecosystems.

5) Analyze existing evidence about the effect of a specific invasive species on native populations in Tennessee and design a solution to mitigate its impact.

6) Research the ways in which an ecosystem has changed over time in response to changes in physical conditions, population balances, human interactions, and natural catastrophes.

7) Compare and contrast auditory and visual methods of communication among organisms in relation to survival strategies of a population.

6.LS4: Biological Change: Unity and Diversity

1) Explain how changes in biodiversity would impact ecosystem stability and natural resources.

2) Design a possible solution for maintaining biodiversity of ecosystems while still providing necessary human resources without disrupting environmental equilibrium.

6.ESS2: Earth's Systems

1) Gather evidence to justify that oceanic convection currents are caused by the sun's transfer of heat energy and differences in salt concentration leading to global water movement.

2) Diagram convection patterns that flow due to uneven heating of the earth.

3) Construct an explanation for how atmospheric flow, geographic features, and ocean currents affect the climate of a region through heat transfer.

4) Apply scientific principles to design a method to analyze and interpret the impact of humans and other organisms on the hydrologic cycle.

5) Analyze and interpret data from weather conditions, weather maps, satellites, and radar to predict probable local weather patterns and conditions.

6) Explain how relationships between the movement and interactions of air masses, high and low pressure systems, and frontal boundaries result in weather conditions and severe storms.

6.ESS3: Earth and Human Activity

1) Differentiate between renewable and nonrenewable resources by asking questions about their availability and sustainability.

2) Investigate and compare existing and developing technologies that utilize renewable and alternative energy resources.

3) Assess the impacts of human activities on the biosphere including conservation, habitat management, species endangerment, and extinction.

6.ETS1: Engineering Design

1) Evaluate design constraints on solutions for maintaining ecosystems and biodiversity.

2) Design and test different solutions that impact energy transfer.

SEVENTH GRADE: OVERVIEW

The academic standards for seventh grade establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of experiences for both science practices and content knowledge. The academic standards for science in seventh grade are research-based and supported by the National Research Council's *Framework for K-12 Science Education.*

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of seventh grade. Disciplinary core ideas for seventh grade include:

Seventh Grade			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications in Technologies for Information Transfer	Biological Change: Unity and Diversity		

The standards incorporated into this grade have been streamlined for the students' K-12 coherent experience for a diversity of learners. The theme for seventh grade science is how matter and reactions are the basis for life science, particularly the molecules that make up life (LS1) DNA/proteins, and their hierarchy to organ systems and heredity; and biogeochemical cycles (LS2) carbon and oxygen cycling through photosynthesis and aerobic cellular respiration. Earth and space science standards are addressed from a perspective based on matter and reactions (atmospheric composition, combustion, and climate change). Tennessee's state mathematics standards are integrated into the science standards, specifically connecting proportional reasoning with whole number multiplication and division. Special attention is given to science literacy through the use of the science and engineering practices. Students are often required to gather information from reliable sources to construct evidenced-based arguments (e.g., 7.LS1.6).

By the end of seventh grade, it is expected that students should be able to demonstrate the skills and content knowledge emphasized in the following standards in preparation for future learning in science and its practice.

SEVENTH GRADE: ACADEMIC STANDARDS

7.PS1: Matter and Its Interactions

1) Develop and use models to illustrate the structure of atoms, including the subatomic particles with their relative positions and charge.

2) Compare and contrast elemental molecules and compound molecules.

3) Classify matter as pure substances or mixtures based on composition.

4) Analyze and interpret chemical reactions to determine if the total number of atoms in the reactants and products support the Law of Conservation of Mass.

5) Use the periodic table as a model to analyze and interpret evidence relating to physical and chemical properties to identify a sample of matter.

6) Create and interpret models of substances whose atoms represent the states of matter with respect to temperature and pressure.

7.LS1: From Molecules to Organisms: Structures and Processes

1) Develop and construct models that identify and explain the structure and function of major cell organelles as they contribute to the life activities of the cell and organism.

2) Conduct an investigation to demonstrate how the cell membrane maintains homeostasis through the process of passive transport.

3) Evaluate evidence that cells have structural similarities and differences in organisms across kingdoms.

4) Diagram the hierarchical organization of multicellular organisms from cells to organism.

5) Explain that the body is a system comprised of subsystems that maintain equilibrium and support life through digestion, respiration, excretion, circulation, sensation (nervous and integumentary), and locomotion (musculoskeletal).

6) Develop an argument based on empirical evidence and scientific reasoning to explain how behavioral and structural adaptations in animals and plants affect the probability of survival and reproductive success.

7) Evaluate and communicate evidence that compares and contrasts the advantages and disadvantages of sexual and asexual reproduction.

8) Construct an explanation demonstrating that the function of mitosis for multicellular organisms is for growth and repair through the production of genetically identical daughter cells.

9) Construct a scientific explanation based on compiled evidence for the processes of photosynthesis, cellular respiration, and anaerobic respiration in the cycling of matter and flow of energy into and out of organisms.

7.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Develop a model to depict the cycling of matter, including carbon and oxygen, including the flow of energy among biotic and abiotic parts of an ecosystem.

7.LS3: Heredity: Inheritance and Variation of Traits

1) Hypothesize that the impact of structural changes to genes (i.e., mutations) located on chromosomes may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

2) Distinguish between mitosis and meiosis and compare the resulting daughter cells.

3) Predict the probability of individual dominant and recessive alleles to be transmitted from each parent to offspring during sexual reproduction and represent the phenotypic and genotypic patterns using ratios.

7.ESS3: Earth and Human Activity

1) Graphically represent the composition of the atmosphere as a mixture of gases and discuss the potential for atmospheric change.

2) Engage in a scientific argument through graphing and translating data regarding human activity and climate.

7.ETS2: Links Among Engineering, Technology, and Applications of Science

1) Examine a problem from the medical field pertaining to biomaterials and design a solution taking into consideration the criteria, constraints, and relevant scientific principles of the problem that may limit possible solutions.

EIGHTH GRADE: OVERVIEW

The academic standards for eighth grade establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of experiences for both science practices and content knowledge. The academic standards for science in eighth grade are research-based and supported by the National Research Council's *Framework for K-12 Science Education*.

The academic standards herein establish the core content and practices of science and engineering, as well as what Tennessee students need to know by the end of eighth grade. Disciplinary core ideas for eighth grade include:

Eighth Grade			
Physical Sciences (PS)	Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Matter and Its Interactions	From Molecules to Organisms: Structure and Process	Earth's Place in the Universe	Engineering Design
Motion and Stability: Forces and Interactions	Ecosystems: Interactions, Energy, and Dynamics	Earth's Systems	Links Among Engineering, Technology, Science, and Society
Energy	Heredity: Inheritance and Variation of Traits	Earth and Human Activity	Applications of Science
Waves and Their Applications in Technologies for Information Transfer	Biological Change: Unity and Diversity		

The standards incorporated into this grade have been streamlined for the students' K-12 coherent experience for a diversity of learners. The themes for science in eighth grade are how forces and motion drive objects in our solar systems (ESS1), move lithospheric plates (ESS2), and how nature's driving forces of geology (ESS2) impact ecosystems via environmental selection for a species (LS4). This content utilizes core ideas from sixth and seventh grade; for example, using a hereditary approach in seventh grade to examine natural selection in eighth grade. Tennessee's state mathematics standards are integrated into the science standards, specifically forces and motion (8.PS2). Special attention is given to science literacy through the use of the science and engineering practices. Students are often required to gather information from reliable sources to construct evidenced-based arguments (e.g., 8.ESS2).

By the end of eighth grade, it is expected that students should be able to demonstrate the skills and content knowledge emphasized in the following standards in preparation for future learning in science and its practice.

EIGHTH GRADE: ACADEMIC STANDARDS

8.PS2: Motion and Stability: Forces and Interactions

1) Design and conduct investigations depicting the relationship between magnetism and electricity in electromagnets, generators, and electrical motors, emphasizing the factors that increase or diminish the electric current and the magnetic field strength.

2) Conduct an investigation to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

3) Create a demonstration of an object in motion and describe the position, force, and direction of the object.

4) Plan and conduct an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

5) Evaluate and interpret that for every force exerted on an object there is an equal force exerted in the opposite direction.

8.PS4: Waves and Their Applications in Technologies for Information Transfer

1) Develop and use models to represent the basic properties of waves including frequency, amplitude, wavelength, and speed.

2) Compare and contrast mechanical waves and electromagnetic waves based on refraction, reflection, transmission, absorption, and their behavior through a vacuum and/or various media.

3) Evaluate the role that waves play in different communication systems.

8.LS4: Biological Change: Unity and Diversity

1) Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change in life forms throughout Earth's history.

2) Construct an explanation addressing similarities and differences of the anatomical structures and genetic information between extinct and extant organisms using evidence of common ancestry and patterns between taxa.

3) Analyze evidence from geology, paleontology, and comparative anatomy to support that specific phenotypes within a population can increase the probability of survival of that species and lead to adaptation.

4) Develop a scientific explanation of how natural selection plays a role in determining the survival of a species in a changing environment.

5) Obtain, evaluate, and communicate information about the technologies that have changed the way humans use artificial selection to influence the inheritance of desired traits in other organisms.

8.ESS1: Earth's Place in the Universe

1) Research, analyze, and communicate that the universe began with a period of rapid expansion using evidence from the motion of galaxies and composition of stars.

2) Explain the role of gravity in the formation of our sun and planets. Extend this explanation to address gravity's effect on the motion of celestial objects in our solar system and Earth's ocean tides.

8.ESS2: Earth's Systems

1) Analyze and interpret data to support the assertion that rapid or gradual geographic changes lead to drastic population changes and extinction events.

2) Evaluate data collected from seismographs to create a model of Earth's structure.

3) Describe the relationship between the processes and forces that create igneous, sedimentary, and metamorphic rocks.

4) Gather and evaluate evidence that energy from the earth's interior drives convection cycles within the asthenosphere which creates changes within the lithosphere including plate movements, plate boundaries, and sea-floor spreading.

5) Construct a scientific explanation using data that explains the gradual process of plate tectonics accounting for A) the distribution of fossils on different continents, B) the occurrence of earthquakes, and C) continental and ocean floor features (including mountains, volcanoes, faults, and trenches).

8.ESS3: Earth and Human Activity

1) Interpret data to explain that earth's mineral, fossil fuel, and groundwater resources are unevenly distributed as a result of geologic processes.

2) Collect data, map, and describe patterns in the locations of volcanoes and earthquakes related to tectonic plate boundaries, interactions, and hotspots.

8.ETS1: Engineering Design

1) Develop a model to generate data for ongoing testing and modification of an electromagnet, a generator, and a motor such that an optimal design can be achieved.

2) Research and communicate information to describe how data from technologies (telescopes, spectroscopes, satellites, and space probes) provide information about objects in the solar system and universe.

BIOLOGY I: COURSE OVERVIEW

The academic standards for High School Biology I establish the content knowledge and skills for Tennessee students in order to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of experiences for both science practices and content knowledge needed in an ever changing world. The academic standards for Biology I are research-based, supported by the National Research Council's *Framework for K-12 Science Education*, and establish the core ideas and practices of science and engineering that will prepare students to use scientific thinking to examine and evaluate knowledge encountered throughout their lives.

The major disciplinary core ideas utilized for Biology I include:

<table>
<tr><th colspan="2">Biology I (BIO1)</th></tr>
<tr><th>Life Sciences (LS)</th><th>Engineering, Technology, and Applications of Science (ETS)</th></tr>
<tr><td>From Molecules to Organisms: Structure and Process
Organic molecules
DNA structure and function
Protein synthesis
Protein structure and function
Cellular differentiation and coordinated functions
Eukaryotic cell cycle
Membrane transport
Photosynthesis and respiration</td><td>Engineering Design</td></tr>
<tr><td>Ecosystems: Interactions, Energy, and Dynamics
Population dynamics
Carbon cycle
Energy transfer
Succession
Biodiversity and ecosystem stability</td><td>Links Among Engineering, Technology, Science, and Society
Molecular biotechnology applications
Ethical debates of biotechnology use</td></tr>
<tr><td>Heredity: Inheritance and Variation of Traits
Sexual reproduction
Phenotype determining factors
Pedigree analysis and predictions</td><td rowspan="2">Applications of Science</td></tr>
<tr><td>Biological Change: Unity and Diversity
Evidence for evolution
Natural selection
Evolutionary processes
Speciation
Global biodiversity patterns
Human activities that impact biodiversity</td></tr>
</table>

Although science is a body of knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Biology I standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

Tennessee's state mathematics standards are integrated into the science standards, specifically LS3.3. Special attention is given to science literacy through the use of the science and engineering practices. Students are required to gather information from reliable sources to construct evidenced-based arguments. Finally, STEM integration is supported both as a stand-alone disciplinary core idea as well as integrated into the life science core ideas. By the end of high school, it is expected that all students should be able to demonstrate the skills and content knowledge emphasized in the following standards.

BIOLOGY I: ACADEMIC STANDARDS

BIO1.LS1: From Molecules to Organisms: Structures and Processes

1) Compare and contrast existing models, identify patterns, and use structural and functional evidence to analyze the characteristics of life. Engage in argument about the designation of viruses as non-living based on these characteristics.

2) Evaluate comparative models of various cell types with a focus on organic molecules that make up cellular structures.

3) Integrate evidence to develop a structural model of a DNA molecule. Using the model, develop and communicate an explanation for how DNA serves as a template for self-replication and encodes biological information.

4) Demonstrate how DNA sequence information is decoded through transcriptional and translational processes within the cell in order to synthesize proteins. Examine the relationship of structure and function of various types of RNA and the importance of this relationship in these processes.

5) Research examples that demonstrate the functional variety of proteins and construct an argument based on evidence for the importance of the molecular structure to its function. Plan and carry out a controlled investigation to test predictions about factors, which should cause an effect on the structure and function of a protein.

6) Create a model for the major events of the eukaryotic cell cycle, including mitosis. Compare and contrast the rates of cell division in various eukaryotic cell types in multicellular organisms.

7) Utilize a model of a cell plasma membrane to compare the various types of cellular transport and test predictions about the movement of molecules into or out of a cell based on the homeostasis of energy and matter in cells.

8) Create a model of photosynthesis demonstrating the net flow of matter and energy into a cell. Use the model to explain energy transfer from light energy into stored chemical energy in the product.

9) Create a model of aerobic respiration demonstrating flow of matter and energy out of a cell. Use the model to explain energy transfer mechanisms. Compare aerobic respiration to alternative processes of glucose metabolism.

BIO1.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Analyze mathematical and/or computational representations of population data that support explanations of factors that affect population size and carrying capacities of populations within an ecosystem. Examine a representative ecosystem and, based on interdependent relationships present, predict population size effects due to a given disturbance.

2) Create a model tracking carbon atoms between inorganic and organic molecules in an ecosystem. Explain human impacts on climate based on this model.

3) Analyze through research the cycling of matter in our biosphere and explain how biogeochemical cycles are critical for ecosystem function.

4) Analyze data demonstrating the decrease in biomass observed in each successive trophic level. Construct an explanation considering the laws of conservation of energy and matter and represent this phenomenon in a mathematical model to describe the transfer of energy and matter between trophic levels.

5) Analyze examples of ecological succession, identifying and explaining the order of events responsible for the formation of a new ecosystem in response to extreme fluctuations in environmental conditions or catastrophic events.

BIO1.LS3: Heredity: Inheritance and Variation of Traits

1) Model chromosome progression through meiosis and fertilization in order to argue how the processes of sexual reproduction lead to both genetic similarities and variation in diploid organisms. Compare and contrast the processes of sexual and asexual reproduction, identifying the advantages and disadvantages of each.

2) Explain how protein formation results in phenotypic variation and discuss how changes in DNA can lead to somatic or germ line mutations.

3) Through pedigree analysis, identify patterns of trait inheritance to predict family member genotypes. Use mathematical thinking to predict the likelihood of various types of trait transmission.

BIO1.LS4: Biological Change: Unity and Diversity

1) Evaluate scientific data collected from analysis of molecular sequences, fossil records, biogeography, and embryology. Identify chronological patterns of change and communicate that biological evolution is supported by multiple lines of empirical evidence that identify similarities inherited from a common ancestor (homologies).

2) Using a model that demonstrates the change in allele frequencies resulting in evolution of a population over many generations, identify causative agents of change.

3) Identify ecosystem services and assess the role of biodiversity in support of these services. Analyze the role human activities have on disruption of these services.

BIO1.ETS2: Links Among Engineering, Technology, Science, and Society

1) Obtain, evaluate, and communicate information on how molecular biotechnology may be used in a variety of fields.

2) Investigate the means by which karyotypes are utilized in diagnostic medicine.

3) Analyze scientific and ethical arguments to support the pros and cons of application of a specific biotechnology technique such as stem cell usage, in vitro fertilization, or genetically modified organisms.

BIOLOGY II: COURSE OVERVIEW

The academic standards for high school Biology II are built on the foundation provided by Biology I (a prerequisite course) and are research-based, supported by the National Research Council's *Framework for K-12 Science Education*. Biology II provides students with the opportunity to focus on a particular aspect of life science in more detail while continuing to provide knowledge that is rooted in the same crosscutting concepts and practices utilized throughout all of the sciences. The academic standards for Biology II focus on organism classification and evolution with in depth analysis of plants and animals.

The major disciplinary core ideas utilized for Biology II include:

<table>
<tr><th colspan="2">Biology II (BIO2)</th></tr>
<tr><td>Life Sciences (LS)</td><td>Engineering, Technology, and Applications of Science (ETS)</td></tr>
<tr><td>From Molecules to Organisms: Structure and Process</td><td>Engineering Design</td></tr>
<tr><td>Ecosystems: Interactions, Energy, and Dynamics</td><td>Links Among Engineering, Technology, Science, and Society (ETS)
• Microscope
• Biotechnology support of the theory of evolution
Engineering and technology applications using living organisms</td></tr>
<tr><td>Heredity: Inheritance and Variation of Traits</td><td rowspan="2">Applications of Science</td></tr>
<tr><td>Biological Change: Unity and Diversity
• History and classification of life
• Plant structure, function, classification, and evolution
• Animal structure, function, classification, and evolution
• Animal social interactions and group behaviors</td></tr>
</table>

Although science is a body of knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Biology II standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

Special attention has been given to mathematics and literacy through the use of the science and engineering practices described above. Students are required to use mathematics in the collection, presentation, and analysis of data, and computational thinking is employed for complex data sets and simulation models. Students are also required to obtain information from reliable sources, evaluate information, and construct evidenced-based arguments. The importance of STEM integration has been stressed by including a set of stand-alone disciplinary core ideas under Engineering, Technology, and Applications of Science, as well as being integrated throughout other major disciplinary core ideas.

Tennessee's state mathematics standards are integrated within the Biology II standards, specifically in the collection and analysis of quantitative data in designed investigations and less specifically in standards throughout that incorporate data measurements and/or analysis. Literacy standards are integrated into the Biology II standards in the development of arguments, collection and evaluation of information, and through the use of graphs as informational texts. STEM applications are incorporated throughout the life science core ideas presented in Biology II, when data collected with technology is used to support and explain observations.

The skills and content knowledge emphasized in the following Biology II standards are intended to provide a deep appreciation of the variety of life forms that have previously existed and currently exist on Earth. Consequently, a more integrated approach to the LS4 disciplinary core idea outlined throughout this document has been implemented, with standards LS4.1-11 focusing on bacteria, archaea, fungi, and protists, standards LS4.12-19 on plants, and LS4.20-28 on animals. In addition, the standards should provide opportunities to practice science, promoting the development of critical consumers of scientific information.

BIOLOGY II: ACADEMIC STANDARDS

BIO2.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Plan and carry out an ethology investigation of a simple organism. Gather, analyze, and present data in tabular and graphical formats. Draw conclusions based on data and communicate findings.

2) Compare innate versus learned behavior. Construct an argument from evidence that shows the value of both types of behavior and their importance to species survival.

3) Obtain information and construct an explanation to support or oppose an adaptive advantage of social behaviors.

BIO2.LS4: Biological Change: Unity and Diversity

1) Use models of viruses, prokaryotes, and eukaryotes to ask questions about characteristics of living things and analyze theories regarding the origin of life on Earth. Construct an argument from evidence supporting the idea that eukaryotes could not exist on the planet if not for prokaryotes.

2) Using information based on the geologic time scale and history of life on Earth, look for patterns in changes in organisms over time and explain how these patterns support the theory of evolution.

3) Use molecular data to construct cladograms depicting phylogenetic relationships between major groups of organisms.

4) Trace changes in classification schemes over time, explaining these changes considering new findings and new interpretations of existing data.

5) Construct an argument from evidence supporting the three domain classification system or opposing the system with a suggested alternative system.

6) Obtain information and compare features of Bacteria and Archaea. Ask questions about the evolution of each group.

7) Using models, compare how the following processes occur in major groups of bacteria: gas exchange; nutrient distribution; energy acquisition and use; response to internal and external stimuli; and, reproduction.

8) Construct an explanation for the evolution of eukaryotes and multicellularity based on evidence supporting the theory of endosymbiosis. Consider examples of extant organisms (viruses, bacteria, and protists) that invade host cells.

9) Using models, compare how the following processes occur in major groups of protists: gas exchange; nutrient distribution; energy acquisition and use; response to internal and external stimuli; and, reproduction.

10) Evaluate information regarding the diversity of protists. Use this information to analyze evolutionary relationships among protists, fungi, plants, and animals.

11) Using models, compare how the following processes occur in major groups of fungi: gas exchange; nutrient distribution; energy acquisition and use; response to internal and external stimuli; and, reproduction.

12) Analyze evolutionary relationships among algae and major groups of plants. In this analysis, consider adaptations necessary for survival in terrestrial habitats.

13) Interpret data supporting current plant classification schemes. Use a dichotomous key to identify plants based on variations in characteristics.

14) Obtain information and ask questions about the advantages and disadvantages of the basic plant life cycle (alternation of generations). Compare variations in this life cycle among major groups of plants.

15) Use a model angiosperm to differentiate plant organs and the tissues from which they are made. Use the model to explain how the plant structures: provide support; regulate gas exchange; obtain and use energy; and, process and distribute nutrients.

16) Design and carry out an investigation examining the function of plant hormones.

17) Develop a model explaining plant tropisms at different scales (cell, tissue, organ, system). Use the model to predict how plants will respond in various environmental conditions.

18) Create an argument from evidence regarding the importance of plant relationships including symbiosis and co-evolutionary relationships (examples: mycorrhizae, Rhizobium, pollination, etc.).

19) Investigate the role of different plant types in ecosystem building and maintenance (examples: soil formation, inhibition of erosion, oxygen production, carbon sequestration, habitats).

20) Create a model to distinguish animal germ layers (endoderm, mesoderm, and ectoderm) and resulting tissue types. Use the model to make predictions regarding phylogenetic relationships among groups of organisms with varying body plans.

21) Construct an argument for the importance of embryological development in understanding relatedness (evolutionary relationships). As part of the argument, compare models of embryological development of protostomes and deuterostomes.

22) Observe examples of organisms from major animal phyla in order to describe the diverse structures associated with the following functions: gas exchange; energy acquisition; nutrient processing and distribution; environmental responses; and reproduction.

23) Design and carry out an investigation examining how major body systems interact to maintain homeostasis of nutrient, energy, water, waste, and/or temperature balance.

24) Obtain and communicate information on how the nervous and endocrine systems in a model vertebrate organism coordinate body functions such as: growth and development; stimuli response and information transmission; and, the maintenance of homeostasis.

25) Create a model demonstrating how the immune system functions in monitoring of and responding to bacterial and viral infectious diseases.

26) Gather and analyze data on ectothermic and endothermic organisms and argue the advantages and disadvantages these organisms possess, considering various environments in which they live and various strategies for survival.

27) Model several reproductive strategies used by example organisms and compare them to explain how each differentially accomplishes reproductive success. Collect information in support of the argument that rapidly reproducing species that produce more young are more resilient.

28) Evaluate scientific data collected from multiple sources to trace animal evolution.

BIO2.ETS2: Links Among Engineering, Technology, Science, and Society

1) Research the development of the microscope and advances in microscopy technology for the discovery and ongoing understanding of microorganisms.

2) Construct an explanation for how classification schemes have changed based on new evidence gained due to advances in biotechnology.

3) Create a timeline depicting how humans have employed engineering and technology to maximize use of microorganisms, plants, and animals for various purposes. Choose one specific example and construct an argument supporting or opposing the use of engineering or technology in this instance.

CHEMISTRY I: COURSE OVERVIEW

The academic standards establish the practices and core content for all Chemistry I courses in Tennessee high schools. The core ideas within the framework and standards are not meant to represent an equal division of material and concepts.

The major disciplinary core ideas utilized for Chemistry I include:

Physical Science (PSCI)
Physical Sciences (PS)
Matter and Its Interactions • Structure and properties of matter • Chemical reactions • Nuclear process
Motion and Stability: Forces and Interactions • Forces and motion • Types of interactions • Stability and instability in physical systems
Energy • Definitions of energy • Conservation of energy and energy transfer • Relationship between energy and forces • Energy in chemical processes and everyday life
Waves and Their Applications in Technologies for Information Transfer • Wave properties • Electromagnetic radiation

Students should explore these chemistry concepts and the seven core concepts (patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and, stability and change) through laboratory techniques, manipulation of chemical quantities, and problem-solving practices. Within the Chemistry I standards, scientific and engineering practices are embedded as a means to learn about specific topics identified for the course. Engaging in these practices with current applications will help students become scientifically literate and astute consumers of scientific information.

Teachers, schools, and districts should use these standards to make decisions concerning the structure and content for Chemistry I classes in Tennessee schools. All chemistry courses must allow students to engage in problem solving, decision making, critical thinking, and applied learning. Chemistry courses are also laboratory based and require a minimum of 30% hands-on investigation. Chemistry laboratories will need to be stocked with the materials and equipment necessary to complete scientific investigations.

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Chemistry I standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

The academic standards for Chemistry I should be the basis for the development of classroom and course-level assessments.

CHEMISTRY I: ACADEMIC STANDARDS

CHEM1.PS1: Matter and Its Interactions

1) Understand and be prepared to use values specific to chemical processes: the mole, molar mass, molarity, and percent composition.

2) Demonstrate that atoms, and therefore mass, are conserved during a chemical reaction by balancing chemical equations.

3) Perform stoichiometric calculations involving the following relationships: mole-mole; mass-mass; mole-mass; mole-particle; and mass-particle. Show a qualitative understanding of the phenomenon of percent yield, limiting, and excess reagents in a chemical reaction through pictorial and conceptual examples. (states of matter liquid and solid; excluding volume of gasses)

4) Use the reactants in a chemical reaction to predict the products and identify reaction classes (synthesis, decomposition, combustion, single replacement, double replacement).

5) Conduct investigations to explore and characterize the behavior of gases (pressure, volume, temperature), develop models to represent this behavior, and construct arguments to explain this behavior. Evaluate the relationship (qualitatively and quantitatively) at STP between pressure and volume (Boyle's law), temperature and volume (Charles's law), temperature and pressure (Gay-Lussac law), and moles and volume (Avogadro's law), and evaluate and explain these relationships with respect to kinetic-molecular theory. Be able to understand, establish, and predict the relationships between volume, temperature, and pressure using combined gas law both qualitatively and quantitatively.

6) Use the ideal gas law, $PV = nRT$, to algebraically evaluate the relationship among the number of moles, volume, pressure, and temperature for ideal gases.

7) Analyze solutions to identify solutes and solvents, quantitatively analyze concentrations (molarity, percent composition, and ppm), and perform separation methods such as evaporation, distillation, and/or chromatography and show conceptual understanding of distillation. Construct an argument to justify the use of certain separation methods under different conditions.

8) Identify acids and bases as a special class of compounds with a specific set of properties.

9) Draw models (qualitative models such as pictures or diagrams) to demonstrate understanding of radioactive stability and decay. Understand and differentiate between fission and fusion reactions. Use models (graphs or tables) to explain the concept of half-life and its use in determining the age of materials (such as radiometric dating).

10) Compare alpha, beta, and gamma radiation in terms of mass, charge, and penetrating power. Identify examples of applications of different radiation types in everyday life (such as its applications in cancer treatment).

11) Develop and compare historical models of the atom (from Democritus to quantum model) and construct arguments to show how scientific knowledge evolves over time, based on experimental evidence, critique, and alternative interpretations.

12) Explain the origin and organization of the Periodic Table. Predict chemical and physical properties of main group elements (reactivity, number of subatomic particles, ion charge, ionization energy, atomic radius, and electronegativity) based on location on the periodic table. Construct an argument to describe how the quantum mechanical model of the atom (e.g., patterns of valence and inner electrons) defines periodic properties. Use the periodic table to draw Lewis dot structures and show understanding of orbital notations through drawing and interpreting graphical representations (i.e., arrows representing electrons in an orbital).

13) Use the periodic table and electronegativity differences of elements to predict the types of bonds that are formed between atoms during chemical reactions and write the names of chemical compounds, including polyatomic ions using the IUPAC criteria.

14) Use Lewis dot structures and electronegativity differences to predict the polarities of simple molecules (linear, bent, trigonal planar, trigonal pyramidal, tetrahedral). Construct an argument to explain how electronegativity affects the polarity of basic chemical molecules.

15) Investigate, describe, and mathematically determine the effect of solute concentration on vapor pressure using the solute’s van ’t Hoff factor on freezing point depression and boiling point elevation.

CHEM1.PS2: Motion and Stability: Forces and Interactions

1) Draw, identify, and contrast graphical representations of chemical bonds (ionic, covalent, and metallic) based on chemical formulas. Construct and communicate explanations to show that atoms combine by transferring or sharing electrons.

2) Understand that intermolecular forces created by the unequal distribution of charge result in varying degrees of attraction between molecules. Compare and contrast the intermolecular forces (hydrogen bonding, dipole-dipole bonding, and London dispersion forces) within different types of simple substances (only those following the octet rule) and predict and explain their effect on chemical and physical properties of those substances using models or graphical representations.

3) Construct a model to explain the process by which solutes dissolve in solvents, and develop an argument to describe how intermolecular forces affect the solubility of different chemical compounds.

4) Conduct an investigation to determine how temperature, surface area, and stirring affect the rate of solubility. Construct an argument to explain the relationships observed in experimental data using collision theory.

CHEM1.PS3: Energy

1) Contrast the concepts of temperature and heat in macroscopic and microscopic terms. Understand that thermal energy is a form of energy and temperature is a measure of average kinetic energy of a group of particles.

2) Draw and interpret heating and cooling curves and phase diagrams. Analyze the energy changes involved in calorimetry by using the law of conservation of energy quantitatively (use of $q = mc\Delta T$) and qualitatively.

3) Distinguish between endothermic and exothermic reactions by constructing potential energy diagrams and explain the differences between the two using chemical terms (e.g. activation energy). Recognize when energy is absorbed or given off depending on the bonds formed and bonds broken.

4) Analyze energy changes to explain and defend the law of conservation of energy.

CHEM1.PS4: Waves and Their Applications in Technologies for Information Transfer

1) Using a model, explain why elements emit and absorb characteristic frequencies of light and how this information is used.

CHEMISTRY II: COURSE OVERVIEW

The academic standards establish the practices and core content for all Chemistry II courses in Tennessee high schools. The core ideas within the framework and standards are not meant to represent an equal division of material and concepts.

The major disciplinary core ideas utilized for Chemistry II include:

Physical Science (PSCI)
Physical Sciences (PS)
Matter and Its Interactions • Structure and properties of matter • Chemical reactions • Nuclear process
Motion and Stability: Forces and Interactions • Forces and motion • Types of interactions • Stability and instability in physical systems
Energy • Definitions of energy • Conservation of energy and energy transfer • Relationship between energy and forces • Energy in chemical processes and everyday life
Waves and Their Applications in Technologies for Information Transfer • Wave properties • Electromagnetic radiation

The Chemistry II standards build on topics that were introduced in Chemistry I with increased rigor. Students should explore these advanced chemistry concepts and the seven core concepts (patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and, stability and change) through laboratory techniques, manipulation of chemical quantities, and advanced problem-solving practices. Within the Chemistry II standards, scientific and engineering practices are embedded as a means to learn about specific topics identified for the course. Engaging in these practices with current applications will help students become scientifically literate and astute consumers of scientific information.

Teachers, schools, and districts should use these standards to make decisions concerning the structure and content for Chemistry II classes in Tennessee schools. All chemistry courses must allow students to engage in problem solving, decision making, critical thinking, and applied learning. Chemistry courses are also laboratory based and require a minimum of 30% hands-on investigation. Chemistry laboratories will need to be stocked with the materials and equipment necessary to complete scientific investigations.

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Chemistry II standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

The academic standards for Chemistry II should be the basis for the development of classroom and course-level assessments.

CHEMISTRY II: ACADEMIC STANDARDS

CHEM2.PS1: Matter and Its Interactions

1) Illustrate and explain the arrangement of electrons surrounding atoms and ions (electron configurations and orbital notation of a specific electron in an element) and relate the arrangement of electrons with observed periodic trends.

2) Gather evidence and perform calculations to determine the composition of a compound.

3) Compare and contrast crystalline and amorphous solids with respect to particle arrangement, strength of bonds, melting and boiling points, bulk density, and conductivity; provide examples of each type.

4) Investigate and use mathematical representations to support Dalton's law of partial pressures and to compare and contrast diffusion and effusion.

5) Obtain data and solve combined and ideal gas law problems and stoichiometry problems at STP and non STP conditions to quantitatively explain the behavior of gases.

6) Use the Van der Waal's equation to support explanations of how real gases deviate from the ideal gas law.

7) Investigate, describe, and mathematically determine the effect of solute concentration on vapor pressure using Raoult's Law and of the solute's van 't Hoff factor on freezing point depression and boiling point elevation.

8) Develop models to show how different types of polymers, such as proteins, nucleic acids, and starches, are formed by repetitive combinations of simple subunits by condensation and addition reactions and to show the diverse bonding characteristics of carbon.

9) Evaluate different organic molecules by naming and drawing the ten simplest linear hydrocarbons and isomers that contain single, double, and/or triple bonds and by identifying and explaining the properties of functional groups.

10) Obtain, evaluate, and communicate information about how carbon's structure and function are used and have influenced society.

11) Conduct a qualitative analysis lab to determine the solubility rules. Use solubility rules to identify spectator ions and write net ionic equations for precipitation reactions.

12) Analyze oxidation and reduction reactions to identify the substances gaining and losing electrons, distinguish between the cathode and anode, predict reactions, and balance oxidation-reduction reactions in acidic or basic solutions.

13) Investigate models and explore uses of electrochemistry (batteries and electrochemical cells).

14) Conduct titrations with standard solutions (monoprotic and diprotic) and an appropriate indicator and/or a pH probe to determine the concentration of an unknown acid or base, and with a weak acid or weak base to determine the Ka or Kb and the pH at the equivalence point.

15) Explain common chemical reactions, including those found in biological systems, using qualitative and quantitative information.

16) Create a model of the atomic substructure including electrons, protons, neutrons, quarks, and gluons.

CHEM2.PS2: Motion and Stability: Forces and Interactions

1) Plan and conduct an investigation to compare the properties of the different types of intermolecular forces in pure substances and in components of a mixture.

2) Make predictions regarding the relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within the molecules and types of intermolecular forces through which the molecules interact.

3) Investigate and use mathematical evidence to support that rates of chemical reactions are determined by details of the molecular collisions.

4) Analyze data and mathematically determine rate equations.

5) Investigate the parameters of chemical equilibria in the laboratory by A) writing and calculating equilibrium expressions (Kc, Kp, Ksp, Ka, Kb); B) calculating Q and determining the direction the reaction will proceed; and, C) calculating equilibrium concentrations given an equilibrium constant and starting amounts.

6) Compare and contrast the strength and dissociation of strong and weak acids and bases by calculating the pH and percent ionization of a solution.

7) Research, investigate, and mathematically explain buffer systems (characteristics and capacities using the Henderson-Hasselbalch equation), including those found in biological systems and polyprotic acids.

CHEM2.PS3: Energy

1) Mathematically determine the enthalpy change for a given reaction using Hess's Law, standard enthalpies of formation, or a given mass of a reactant.

2) Apply scientific principles and mathematical representations to predict if a chemical reaction is spontaneous using Gibb's Free Energy, $\Delta G = \Delta H - T\Delta S$.

3) Apply scientific and engineering ideas to build, evaluate, and refine a fuel cell model (e.g., graphical representation or as a project) with specific design constraints.

4) Collect and use data from the synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions.

5) Use Coulomb's law and patterns of valence electron configurations to explain trends in ionization energies and reactivity of pure elements.

6) Explain the relationships between potential energy, distance between approaching atoms, bond length, and bond energy using graphical representations.

7) Investigate and explain the energy changes in biological systems (such as the combustion of sugar and photosynthesis) both qualitatively and quantitatively.

8) Research pyrotechnics and use concepts in thermodynamics, stoichiometry, oxidation reduction, and kinetics to design and create a low intensity sparkler.

CHEM2.PS4: Waves and Their Applications in Technologies for Information Transfer

1) Investigate and contrast the mechanism of energy changes and the appearance of absorption and emission spectra.

2) Apply scientific principles and mathematical representations ($C=\lambda\nu$ and $E=h\nu$) to explain that spectral lines are the result of and correspond to transitions between energy levels.

EARTH AND SPACE SCIENCE: COURSE OVERVIEW

The Earth and Space Science course examines the role of Earth's place in the universe, the interplay of Earth's systems, and the interrelationships between Earth's systems and human activity. Inherent in this course is a look at how Earth has changed over time and the dynamics that continue to affect it. As events have impacts on the hydrosphere, biosphere, atmosphere, and geosphere, there are also sphere-to-sphere dynamics taking place in the short, medium, and long-term. This is a lab course, with an emphasis on important 21st century critical thinking skills.

Earth and Space Science (ESS)
Earth and Space Sciences (ESS)
Earth's Place in the Universe • The universe and its stars • Earth and the solar system • The history of planet Earth
Earth's Systems • Earth materials and systems • Plate tectonics and large scale system interactions • The roles of water in Earth's surface processes • Weather and climate • Biogeology
Earth and Human Activity • Natural resources • Natural hazards • Human impacts on Earth systems • Global climate change

The eight science and engineering practices describe how students should learn and demonstrate knowledge of the content outlined in the content standards. Engaging in these practices helps students become scientifically literate and astute consumers of scientific information. The seven core concepts (patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and, stability and change) are reinforced in the appropriate context of the core science content through hands-on instruction in the classroom.

Teachers, schools, and districts should use these standards and indicators to make decisions concerning the structure and content of Earth and Space Science. All courses should include instruction in the practices of science and engineering, allowing students to engage in problem solving, decision making, critical thinking, and applied learning. All Earth and Space Science courses are laboratory courses requiring a minimum of 30% hands-on investigation. As such, labs should be stocked with the materials and equipment necessary to complete scientific investigations.

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Earth and Space Science standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

The academic standards and performance indicators establish the practices and core content for all Earth and Space Science courses in Tennessee high schools. The core ideas within the standards are not meant to represent an equal division of material and concepts. Therefore, the number of indicators per core idea should not be expected to be equal, nor should equal numbers of performance indicators within each standard be expected.

EARTH AND SPACE SCIENCE: ACADEMIC STANDARDS

ESS.ESS1: Earth's Place in the Universe

1) Construct an explanation regarding the rapid expansion of the universe based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

2) Construct a model using astronomical distances to explain the spatial relationships and physical interactions among planetary systems, stars, multiple-star systems, star clusters, galaxies, and galactic groups in the universe.

3) Analyze and interpret data about the mass of a star to predict its composition, luminosity, and temperature across its life cycle, including an explanation for how and why it undergoes changes at each stage.

4) Communicate scientific ideas to explain the nuclear fusion process and how elements with an atomic number greater than helium have been formed in stars, supernova explosions, or exposure to cosmic rays.

5) Analyze and compare image data from instruments used to study deep space (e.g., visible, infrared, radio, refracting and reflecting telescopes, and spectrophotometer). Evaluate the strengths and weaknesses of the instrumentation.

6) Recognize how advances in deep space research instrumentation over the last 30 years have led to new understandings of Earth's place in the universe and how these advances have benefitted society.

7) Analyze and interpret data to compare, contrast, and explain the characteristics of objects in the solar system including the sun, planets and their satellites, planetoids, asteroids, and comets. Characteristics include: mass, gravitational attraction, diameter, and composition.

8) Use mathematical or computational representations to predict motions of the various kinds of objects in our solar system, including planets, satellites, comets, and asteroids, and the influence of gravity, inertia, and collisions on these motions.

9) Evaluate the evidence for the role of gravitational force and heat production in theories about the origin and formation of Earth. Design a research study to confirm or refute one aspect of such evidence.

10) Summarize available sources of data within the solar system which provide clues about Earth's formation. Using engineering principles, design a means to gather more data.

ESS.ESS2: Earth's Systems

1) Given an environmental disaster, analyze its effect upon the geosphere, hydrosphere, atmosphere, and/or biosphere, including sphere-to-sphere interactions. Analysis should conclude with an identification of future research to improve our ability to predict such interactions.

2) Construct an argument based on evidence about how global and regional climate is impacted by interactions among the Sun's energy output, tectonic events, ocean circulation, vegetation, and human activities. The argument should include discussion of a variety of time scales from sudden (volcanic ash clouds) to intermediate (ice ages) to long-term tectonic cycles.

3) Communicate scientific and technical information to explain how evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle, and crust.

4) Analyze surface features of Earth and identify and explain the geologic processes responsible for their formation.

5) Develop a visual model to illustrate the formation and reformation of rocks over time including processes such as weathering, sedimentation, and plate movement. The model should include a comparison of the physical properties of various rock types, common rock-forming minerals, and continental rocks versus the oceanic crust.

6) Make and defend a claim based on evidence to describe the formation and on-going availability of mined resources such as phosphorous, platinum, rare minerals, rare earth elements, and/or fossil fuels.

7) Apply scientific principles regarding thermal convection and gravitational movement of dense materials to predict the outcomes of continued development and movement of lithospheric plates from their growing margins at a divergent boundary (mid-ocean ridge) to their destructive margin at a convergent boundary (subduction zone).

8) Using maps and numerical data, evaluate the claims, evidence, and reasoning that forces due to plate tectonics cause earthquake activity, volcanic eruptions, and mountain building.

9) Design a research study to examine an area of increasing seismic or volcanic activity and predict what will occur in that area over the next month, year, and decade. The description should include the instruments and measures to be used in the study and an explanation of their capabilities and limitations.

10) Construct a model which shows the interactions between processes of the hydrologic cycle and the greenhouse effect.

11) Obtain, evaluate, and communicate information about human or natural threats to Tennessee.

12) Engage in an argument from evidence to explain the degree to which the dynamics of oceanic currents could contribute to at least one aspect of climate change.

13) Use a model to predict how variations in the flow of energy through radiation, conduction, and convection into and out of Earth's systems could contribute to global atmospheric processes and climactic effects.

14) Using data, weather maps, and other scientific tools, predict weather conditions from an analysis of the movement of air masses, high and low pressure systems, and frontal boundaries.

15) Use satellite-based image datasets to compare and explain how weather and climate patterns at various latitudes, elevations, and proximities to water and ocean currents are a function of heat, evaporation, condensation, and rotation of the planet. The comparison should also include an examination of the same location across various seasons or years.

16) Design a mathematical model of Earth's energy budget showing how the electromagnetic radiation from the sun in watts/ m2 is reflected, absorbed, stored, redistributed among the atmosphere, ocean, and land systems, and reradiated back into space. The model should provide a means to predict how changes in greenhouse gases could affect Earth's temperatures.

17) Analyze the multiple sources of energy that provide power in the state of Tennessee and compare them to each other and to an alternative energy source. The analysis should include their functional components (such as infrastructure cost, on-going costs, safety, and reliability), and their social, cultural, and environmental impacts (including emissions of greenhouse gases).

18) Identify the organisms that are major drivers in the global carbon cycle and trace how greenhouse gases are continually moved through the carbon reservoirs and fluxes represented by the ocean, land, life, and atmosphere.

ESS.ESS3: Earth and Human Activity

1) Identify a geographical region or small area where energy and mineral resources are scarce and evaluate competing design solutions for developing, managing, and utilizing these energy and mineral resources based on a cost-benefit analysis.

2) Obtain, evaluate, and communicate information on how natural resource availability, natural hazard occurrences, and climatic changes impact individuals and society.

3) Design, evaluate, or refine a technological solution that reduces impacts of human activities on natural systems.

4) Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

ECOLOGY: COURSE OVERVIEW

The academic standards for Ecology establish the content knowledge and skills for Tennessee students in order to prepare them for the rigorous levels of higher education and future job markets. The course provides students with an opportunity to develop an understanding of interrelationships in the natural world in addition to allowing them to analyze human impacts. The academic standards for Ecology are research-based, supported by the National Research Council's *Framework for K-12 Science Education*, and establish the core ideas and practices of science and engineering that will prepare students to use scientific thinking to examine and evaluate knowledge encountered throughout their lives.

The major disciplinary core ideas utilized for Ecology include:

Ecology (ECO)		
Life Sciences (LS)	Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
From Molecules to Organisms: Structures and Process	Earth's Place in the Universe	Engineering Design
Ecosystems: Interactions, Energy, and Dynamics • Interdependent relationships in ecosystems • Cycles of matter and energy transfer in ecosystems • Ecosystems dynamics, functioning, and resilience	Earth's Systems	Link Among Engineering, Technology, Science, and Society • Interdependence of science, engineering, and technology • Influence of engineering, technology, and science on society and the natural world
Heredity: Inheritance and Variation of Traits	Earth and Human Activity • Natural resources • Natural hazards • Human impacts on Earth systems • Global climate change	Applications of Science
Biological Change: Unity and Diversity • Natural selection • Adaptation • Biodiversity and humans		

Although science is a body of knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science. These practices are not intended to be a sequence of steps nor or they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Ecology standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

Tennessee's state mathematics and literacy standards are integrated within the science standards. Special attention has been given to science literacy through the use of the science and engineering practices. Students are required to gather information from reliable sources to construct evidence-based arguments. STEM integration is supported both as a stand-alone disciplinary core idea..

By the end of the Ecology course, it is expected that all students should be able to demonstrate the skills and content knowledge emphasized in the following standards.

ECOLOGY: ACADEMIC STANDARDS

ECO.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Construct explanations for patterns relating to climate, flora, and fauna found in major terrestrial biomes (deserts, temperate grasslands, temperate forests, tropical grasslands, tropical forests, taiga, and tundra).

2) Research examples of adaptations of organisms in major marine and freshwater ecosystems. Develop an explanation for the formation of these adaptations and predict how the organisms would be affected by environmental disturbances or long-term ecological changes.

3) Create a model of an ecosystem depicting the interrelationships among organisms with a variety of niches. Use the model to explain resource needs of these organisms.

4) Compare patterns of stratification and zonation in various terrestrial and aquatic ecosystems. Construct an argument regarding the importance of these patterns in ecosystem diversity.

5) Using the laws of conservation of energy, create a model of energy flow through the biosphere. Use the model to explain limitations in energy transfer and the need for ongoing energy input.

6) Compare pyramids of energy, numbers, and biomass to calculate rates of productivity within food chains and food webs among various biomes. Using mathematics, explain the relationship between biomass and trophic levels.

7) Use models to explain relationships among biogeochemical cycles (water, carbon, nitrogen, phosphorus).

8) Create a diagram tracing carbon through the processes of photosynthesis and respiration. Use the diagram to construct an explanation for the importance of photosynthesis and respiration in the carbon cycle.

9) Construct an argument from evidence regarding the importance of the microbial community in nutrient cycling.

10) Plan and carry out an investigation measuring species diversity (richness and evenness) and density in a local ecosystem.

11) Obtain information regarding distribution patterns (clumped, uniform, random) and make predictions regarding types of organisms that will exhibit each type.

12) Use mathematical models to construct an explanation for population growth patterns and rates observed in ecosystems. Account for both density-dependent and density-independent factors in your explanation.

13) Analyze data regarding exponential and logistic population growth patterns. Use the data to create mathematical models to make predictions regarding carrying capacity.

14) Obtain information regarding survivorship curves and reproductive strategies of various species. Choose one of these strategies and construct an argument regarding its effectiveness.

15) Compare types of competition and construct an explanation for the importance of niche differentiation in response to competition.

16) Use a mathematical model to examine predator-prey interactions. Based on the model, construct an argument regarding the importance of predators in maintaining stability of prey populations.

17) Based on information obtained from research, construct explanations regarding mechanisms by which prey protect themselves from predation (including herbivory).

18) Use models to explain the impacts of types of symbiosis on the species involved in the relationship.

19) Carry out an investigation of stability and change within a local ecosystem. Identify signs of succession (primary or secondary). Based on investigation findings, make predictions regarding future changes in this ecosystem.

20) Plan and carry out an investigation examining kinesis and taxis in a simple organism. Construct and share explanations regarding observations.

21) Gather information regarding types of learned behaviors (fixed action patterns, imprinting, imitation, habituation, trial-and-error, associative learning – classical conditioning, operant conditioning). Ask questions regarding the importance of these behaviors in species survival.

22) Construct an explanation for the relationship between sexual selection and sexual dimorphism.

23) Obtain and evaluate information regarding the relationship between altruistic behavior and kin selection.

ECO.LS4: Biological Change: Unity and Diversity

1) Develop and revise a system for classifying organisms. Justify choice of information (morphology, molecular data, energy acquisition, habitat, niche, trophic level, reproduction, etc.) used in developing your system.

2) Construct an argument, citing evidence, supporting the influence of natural selection on changes in populations over time.

3) Design and carry out an investigation examining the importance of animal behaviors and plant tropisms for survival.

4) Engage in argument from evidence regarding the importance of coevolution in species interactions (competition, predation, symbiosis).

5) Construct an explanation for the importance of keystone species in ecosystem stability.

6) Compare resource needs of specialists versus generalists. Construct an explanation regarding the vulnerability of specialists when faced with ecosystem disturbances.

7) Research and evaluate the effectiveness of strategies for maintenance of biodiversity.

ECO.ESS3: Earth and Human Activity

1) Research and evaluate the effectiveness of public lands (state parks, national parks, wildlife refuges, wilderness areas) in sustaining biodiversity.

2) Construct an argument in support of protection of native species. Develop responses to anticipated counterarguments.

3) Engage in argument from evidence regarding the impacts of human activity on climate change. Design solutions to address these impacts.

ECO.ETS2: Links Among Engineering, Technology, Science, and Society

1) Engage in argument from evidence regarding the impact engineering and technology have on biodiversity.

2) Research and communicate information on a career in ecology. Analyze the role of engineering, technology, and science in that career.

ENVIRONMENTAL SCIENCE: COURSE OVERVIEW

The academic standards for Environmental Science establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with an opportunity to develop an understanding of interrelationships in the natural world. In addition, it allows them to identify natural and man-made environmental problems and design and evaluate possible solutions for these problems. The academic standards for Environmental Science are research-based, supported by the National Research Council's *Framework for K-12 Science Education*. The standards establish the core ideas and practices of science and engineering that will prepare students to use scientific thinking to examine and evaluate knowledge encountered throughout their lives.

The major disciplinary core ideas utilized for Environmental Science include:

<table>
<tr><th colspan="3">Environmental Science (EVSC)</th></tr>
<tr><th>Life Sciences (LS)</th><th>Earth and Space Sciences (ESS)</th><th>Engineering, Technology, and Applications of Science (ETS)</th></tr>
<tr><td>From Molecules to Organisms: Structures and Process</td><td>Earth's Place in the Universe</td><td>Engineering Design</td></tr>
<tr><td>Ecosystems: Interactions, Energy, and Dynamics
• Interdependent relationships in ecosystems
• Cycles of matter and energy transfer in ecosystems
• Ecosystems dynamics, functioning, and resilience</td><td>Earth's Systems
• Earth materials and systems
• Plate tectonics and large scale system interactions
• The roles of water in Earth's surface processes
• Weather and climate</td><td>Links Among Engineering, Technology, Science, and Society
• Interdependence of science, engineering, and technology
• Influence of engineering, technology, and science on society and the natural world</td></tr>
<tr><td>Heredity: Inheritance and Variation of Traits</td><td rowspan="2">Earth and Human Activity
• Natural resources
• Natural hazards
• Human impacts on Earth systems
• Global climate change</td><td rowspan="2">Applications of Science
• Importance of science practices in understanding the natural world</td></tr>
<tr><td>Biological Change: Unity and Diversity
• Natural selection
• Adaptation
• Biodiversity and humans</td></tr>
</table>

Although science is a body of knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Environmental Science standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

Tennessee's state mathematics and literacy standards are integrated within the science standards. Special attention has been given to science literacy through the use of the science and engineering practices. Students are required to gather information from reliable sources to construct evidence-based arguments. STEM integration is supported both as a stand-alone disciplinary core idea, as well as being embedded in Life and Earth and Space Sciences Core Ideas.

By the end of the Environmental Science Course, it is expected that all students should be able to demonstrate the skills and content knowledge emphasized in the following standards.

ENVIRONMENTAL SCIENCE: ACADEMIC STANDARDS

EVSC.LS2: Ecosystems: Interactions, Energy, and Dynamics

1) Using a variety of data sources, construct an explanation for the impact of climate, latitude, altitude, geology, and hydrology patterns on plant and animal life in various terrestrial biomes.

2) Develop an explanation of behavioral and physical adaptations organisms have for life in aquatic habitats with varying chemical and physical features.

3) Using mathematical models, support arguments regarding the effects of biotic and abiotic factors on carrying capacity for populations within an ecosystem.

4) Compare and contrast production (photosynthesis, chemosynthesis) and respiratory (aerobic respiration, anaerobic respiration, consumption, decomposition) processes responsible for the cycling of matter and flow of energy through an ecosystem. Using evidence, construct an argument regarding the importance of homeostasis in maintaining these processes in ecosystems.

5) Use a mathematical model to explain energy flow through an ecosystem. Using the first and second laws of thermodynamics, construct an explanation for: A) necessity for constant energy input; B) limitations on energy transfer from one trophic level to the next; and, C) limitations on number of trophic levels that can be supported.

6) Evaluate the interdependence among major biogeochemical cycles (water, carbon, nitrogen, phosphorus) in an ecosystem and recognize the importance each cycle has in maintaining ecosystem stability.

7) Examine stability and change within an ecosystem by using a model of succession (primary or secondary) to predict impacts of disruption on an ecosystem.

EVSC.LS4: Biological Change: Unity and Diversity

1) Construct an explanation based on scientific evidence for mechanisms of natural selection that result in behavioral, anatomical, and physiological adaptations in populations.

2) Justify claims with scientific evidence that changes in environmental conditions lead to speciation and extinction.

3) Evaluate the impact of habitat fragmentation and destruction, invasive species, overharvesting, pollution, and climate change on biodiversity (genetic, species, and ecosystem).

4) Engage in argument from scientific evidence critiquing effectiveness of the Endangered Species Act. Give specific examples to support your argument.

EVSC.ESS2: Earth's Systems

1) Research the development of the theory of plate tectonics. Use the theory to construct an explanation for how changes in Earth's crust cause mountain formation, volcanoes, earthquakes, and tsunamis. Provide evidence to support the explanation using information pertaining to plate boundary types (divergent, convergent, transform).

2) Considering Earth's position within our solar system, use a model to demonstrate the causes of day length, seasons, and climate.

3) Analyze the composition of the Earth's atmosphere. Obtain information and use graphs to observe patterns regarding stability and change within the Earth's atmospheric composition (O_2, N_2, CO_2, etc.) over geologic time.

4) Differentiate weather and climate and analyze and interpret data examining naturally occurring patterns pertaining to each.

5) Plan and carry out an investigation examining the chemical and physical properties of water and the impact of water on Earth's topography. Analyze data and share findings.

6) Develop a model to explain soil formation and the flow of matter in the rock cycle.

EVSC.ESS3: Earth and Human Activity

1) Research Earth's natural resources (renewable and nonrenewable resources). Construct an argument from evidence supporting the claim that a particular type of resource is important for humans.

2) Interpret graphical data representing global human population growth over time. Look for patterns within this data and construct possible explanations for the patterns. Revise the explanations as needed based on research.

3) Obtain and evaluate information regarding demographics for a variety of countries. Construct an explanation for varying fertility rates and life expectancies between countries and throughout human history. Taking into account demographic transition, predict what trends are likely to occur in various countries over time.

4) Gather, organize, analyze, and present data on current land use trends by humans. Based on analysis, predict future trends.

5) Plan and carry out an investigation examining best management practices in water usage, agriculture, forestry, urban/suburban development, mining, or fishing and communicate findings.

6) Use a model to make predictions regarding the impact of topsoil loss due to erosion resulting from human activity. Design, evaluate, and revise a solution to preserve topsoil.

7) Construct an argument including claim, evidence, and scientific reasoning regarding the impact of the Green Revolution on agricultural practices, food availability, and the environment.

8) Research information on the environmental impacts of genetically modified organisms and engage in debate regarding pros and cons of this agricultural technology.

9) Evaluate ecosystem services provided by forests ecosystems. Construct an explanation for human impact on these services.

10) Using scientific data, analyze effectiveness of conservation versus preservation efforts. Obtain and communicate information on organizations involved in protecting natural resources.

11) Define problems and suggest solutions associated with using, conserving, and recycling energy and mineral resources taking into account economic, social, and environmental costs and benefits.

12) Ask questions about technology needed to develop alternative energy sources and obtain information from various sources to answer those questions.

13) Analyze and interpret data on the effects of land, water, and air pollution on the environment and on human health. Propose solutions for minimizing pollution from specific sources.

14) Obtain and communicate information on environmental laws pertaining to the regulation of pollution and on regulatory agencies. Provide a specific example of how a given business/industry would comply with such regulations.

15) Evaluate current methods of waste management and reduction and design possible improvements.

16) Obtain, evaluate, and communicate scientific information tracing the breakdown of ozone caused by chlorofluorocarbons and the effectiveness of efforts to address this environmental problem.

17) Using mathematics and computational thinking, analyze data linking human activity to climate change. Design solutions to address human impacts on climate change.

18) Use mathematics to calculate ecological footprints. Develop a personal plan for reducing your impact on the environment.

EVSC.ETS2: Links Among Engineering, Technology, Science, and Society

1) Engage in argument from evidence on the role engineering and technology play in a sustainable human society.

2) Research and communicate information on an environmental science career. Analyze the role of society, engineering, technology, and science in that career.

EVSC.ETS3: Applications of Science

1) Plan and carry out an investigation of a local ecosystem to assess human impacts. Based on your findings, design and evaluate a solution to minimize impacts.

GEOLOGY: COURSE OVERVIEW

The Geology course examines Earth's history and changes over time, Earth's surface features and interior, and the processes that affect life on Earth. Also included in this course is a look at the tools used to study the Earth, rocks, minerals, and natural resources. As Earth events have impacts on the hydrosphere, biosphere, atmosphere, and geosphere, there are also sphere-to-sphere dynamics taking place in the short, medium, and long-term. This is a lab course, with an emphasis on important 21st century critical thinking skills.

Geology (GEO)	
Earth and Space Sciences (ESS)	Engineering, Technology, and Applications of Science (ETS)
Earth's Place in the Universe • The history of planet Earth	Engineering Design
Earth's Systems • Earth materials and systems • Plate tectonics and large scale system interactions • The roles of water in Earth's surface processes • Biogeology	Links Among Engineering, Technology, Science, and Society • Interdependence of science, engineering, and technology • Influence of engineering, technology, and science on society and the natural world
Earth and Human Activity • Natural resources • Natural hazards • Human impacts on Earth systems	Applications of Science

The eight science and engineering practices describe how students should learn and demonstrate knowledge of the content outlined in the content standards. Engaging in these practices helps students become scientifically literate and astute consumers of scientific information. The seven core concepts (patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and, stability and change) are reinforced in the appropriate context of the core science content through hands-on instruction in the classroom.

Teachers, schools, and districts should use these standards and indicators to make decisions concerning the structure and content of the Geology course. All courses should include instruction in the practices of science and engineering, allowing students to engage in problem solving, decision making, critical thinking, and applied learning. All Geology courses are laboratory courses requiring a minimum of 30% hands-on investigation. As such, labs should be stocked with the materials and equipment necessary to complete scientific investigations.

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The academic standards and performance indicators establish the practices and core content for all Geology courses in Tennessee high schools. The core ideas within the standards are not meant to represent an equal division of material and concepts. Therefore, the number of indicators per core idea should not be expected to be equal, nor should equal numbers of performance indicators within each standard be expected.

GEOLOGY: ACADEMIC STANDARDS

GEO.ESS1: Earth's Place in the Universe

1) Compare and contrast methods for constructing accounts of Earth's formation, early history, and/or changes in environmental conditions on Earth over time.

2) Evaluate evidence used to explain the ongoing changes in the Earth's system over geologic time due to interactions among the solid Earth, hydrosphere, and atmosphere.

3) Evaluate the geologic evidence (including index fossils, absolute and relative dating methods, superposition, and/or crosscutting relationships) used to infer the age of the Earth. Design a research study to confirm or refute one aspect of such evidence.

GEO.ESS2: Earth's Systems

1) Analyze surface features of Earth in order to identify geologic processes (including weathering, erosion, deposition, and glaciation) that are likely to have been responsible for their formation.

2) Engage in an argument from geoscience data to assert that changes to Earth's surface can create feedbacks that cause changes to other Earth systems.

3) Create a visual model describing the processes responsible for forming the three rock groups (sedimentary, igneous, and metamorphic) and explaining their characteristics.

4) Classify minerals and rocks on the basis of their physical and chemical properties and the environment in which they were formed.

5) Distinguish between the physical and chemical properties of minerals.

6) Investigate the structure and geometry of crystals.

7) Communicate scientific and technical information about how the dynamic nature of the rock cycle accounts for the interrelationships among rock and mineral types, and describe how the total amount of material stays the same throughout formation, weathering, sedimentation, and reformation.

8) Develop a visual model to illustrate the formation and reformation of rocks over time including processes such as weathering, sedimentation, and plate movement. The model should include a comparison of the physical properties of various rock types, common rock-forming minerals, and continental rocks versus the oceanic crust.

9) Develop a model that combines the rock cycle and the carbon cycle, which explains what leads up to and follows a major volcanic eruption and its effect on carbon storage and fluxes.

10) Conduct research, provide a rationale, plan, and conduct an investigation of the properties of water and its effects on Earth materials and surface processes. The rationale should take into account processes of the hydrologic cycle, including evaporation, condensation, precipitation, surface runoff, and groundwater percolation, infiltration, and transpiration.

11) Design a solution to a complex real-world problem caused by the dynamic nature of rivers and streams which erode and transport sediment, change their course, and flood their banks in natural and recurring patterns.

12) Obtain, evaluate, and communicate information about man-made and natural threats (e.g., mining, pollution, erosion, runoff, floods, and earthquakes) to Tennessee watersheds.

13) Communicate scientific and technical information to explain how evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle, and crust.

14) Apply scientific principles regarding thermal convection and gravitational movement of dense materials to predict the outcomes of continued development and movement of lithospheric plates from their growing margins at a divergent boundary (mid-ocean ridge) to their destructive margin at a convergent boundary (subduction zone).

15) Using maps and other data types, predict how plate tectonics cause earthquake activity, volcanic eruptions, and mountain building.

16) Analyze the effect of an earthquake upon the geosphere, hydrosphere, atmosphere, and/or biosphere, including sphere-to-sphere interactions. Analysis should conclude with an identification of future research to improve our ability to predict such interactions.

GEO.ESS3: Earth and Human Activity

1) Use a topographic map and a geologic map to determine an ideal location for a Tennessee electricity-generating facility to provide solar, wind, nuclear, hydroelectric, or other renewable/nonrenewable power.

2) Make and defend a claim based on evidence to describe the formation and future availability of mined resources (e.g., phosphorous, platinum, and fossil fuels).

3) Evaluate the evidence and reasoning supporting claims about the impact of human activities on groundwater quality. The evaluation should include data related to multiple factors (e.g., precipitation, topography, porosity, and run-off).

4) Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources in areas where they are scarce. Compare solutions in terms of environmental impact, sustainability, and cost.

GEO.ETS2: Links Among Engineering, Technology, Science, and Society

1) Read, interpret, and analyze a combination of ground-based observations, satellite data, and computer models to demonstrate the interconnectedness of the geosphere, atmosphere, hydrosphere, and biosphere.

2) Design, build, and refine a device to reduce or eliminate the effect of weathering, erosion, deposition, or other land-surface changes that could be used by the Army Corps of Engineers, Tennessee Valley Authority, Department of Highways, or other agency to improve the road or water systems in Tennessee.

3) Plan and carry out an investigation using a computer-based geographical information tool such as Google Earth, ArcGIS, or My NASA Data to examine the impact of human activities on Earth's surface features.

HUMAN ANATOMY AND PHYSIOLOGY: COURSE OVERVIEW

The academic standards for high school Human Anatomy and Physiology are built on the foundation provided by Biology I (a prerequisite course) and are research-based, supported by the National Research Council's *Framework for K-12 Science Education*. Human Anatomy and Physiology provides students with the opportunity to focus on a particular aspect of life science in more detail while continuing to provide knowledge that is rooted in the same crosscutting concepts and practices utilized throughout all of the sciences. The academic standards for Human Anatomy and Physiology are focused on an in depth analysis of the human organ systems and how they function to support life.

The major disciplinary core ideas utilized for Human Anatomy and Physiology include:

Human Anatomy and Physiology (HAP)	
Life Sciences (LS)	Engineering, Technology, and Applications of Science (ETS)
From Molecules to Organisms: Structure and Process • Human body organization to accomplish life • Integumentary system • Skeletal system • Muscular system • Cardiovascular system • Immune and lymphatic systems • Digestive system • Urinary system • Endocrine system • Nervous system • Reproductive system	Engineering Design • Artificial organ design considerations
Ecosystems: Interactions, Energy, and Dynamics	Links Among Engineering, Technology, Science, and Society • Technology application in disease diagnosis and/or treatment • Technology application to enhance human anatomy and/or physiology
Heredity: Inheritance and Variation of Traits	Applications of Science
Biological Change: Unity and Diversity	

Although science is a body of knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Human Anatomy and Physiology standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

Special attention has been given to mathematics and literacy through the use of the science and engineering practices described above. Students are required to use mathematics in the collection, presentation, and analysis of data, and computational thinking is employed for complex data sets and simulation models. Students are also required to obtain information from reliable sources, evaluate information, and construct evidence-based arguments. The importance of STEM integration has been stressed by including a set of stand-alone disciplinary core ideas under Engineering, Technology, and Applications of Science, as well as being integrated throughout other major disciplinary core ideas.

Tennessee's state mathematics standards are integrated throughout the Human Anatomy and Physiology standards that incorporate data measurements and/or analysis. Literacy standards are integrated throughout as well when informational texts are used to gather information on anatomical structures and functions and/or when oral or written explanations are provided for how structures support physiological mechanisms. STEM applications are incorporated throughout the life science core ideas, in addition to the ETS core ideas, when data collected with technology and/or technology applications are used to support and explain observations.

The skills and content knowledge emphasized in the following Human Anatomy and Physiology standards are intended to provide a deep appreciation for normal and abnormal human structures and functions that support life. In addition, they should provide opportunities to practice science, promoting the development of critical consumers of scientific information.

HUMAN ANATOMY AND PHYSIOLOGY: ACADEMIC STANDARDS

HAP.LS1: From Molecules to Organisms: Structures and Processes

Core Idea: The human body is organized to accomplish life processes.

1) Investigate the organization of the human body in relation to its ability to accomplish life functions and construct an explanation for the relationship between anatomy and physiology.

2) Differentiate the major organ systems of the human body by their anatomy and physiology and engage in argument about defined boundaries due to their functional connectivity.

3) Describe the organizational levels of the human body and observe patterns in cell types and tissue types across organ systems.

4) Use a human model to differentiate the major body cavities and organs located within them. Describe the model using proper anatomical and directional terminology for body regions, planes, and cavities.

5) Explain homeostasis and describe how it is accomplished through feedback mechanisms that utilize receptors and effectors.

Core Idea: The Integumentary system provides protection, temperature homeostasis, and sensation

6) Describe the anatomical structures of the integumentary system and explain their role in the physiological processes of protection, temperature homeostasis, and sensation.

7) Diagram a cross-sectional image of skin layers identifying the microscopic components and describe the life cycle of cells that maintain these layers.

Core Idea: The Skeletal system provides support, protection, movement, storage, and hematopoiesis.

8) Identify major bones within the axial and appendicular divisions, describing their physiological roles in creating a body scaffold, internal organ protection, and anchor points for skeletal muscles participating in movement.

9) Diagram microscopic bone structures, identifying regions that participate in hematopoiesis and storage of minerals and fat.

10) Explain the processes of bone formation, growth, and repair.

Core Idea: Muscular systems provide movement and temperature homeostasis.

11) Differentiate visceral, cardiac, and skeletal muscle tissues based on anatomical criteria and their physiological role in the movement of body parts and/or substances.

12) Model the gross and microscopic anatomy of skeletal muscle and a muscle fiber and use the model to identify and explain the roles of subcellular structures that participate in the events of muscle fiber contraction and heat generation.

13) Model the anatomical connections between the skeletal system and muscular system and explain how they generate movement through antagonistic muscle groups.

Core Idea: The Cardiovascular system provides transport of materials for homeostatic control and protection throughout the body.

14) Describe, in terms of structure and function, the systemic and pulmonary paths of the cardiovascular system.

15) Prepare and/or use a model of a human heart to explain systole and diastole and the heart's internal and external control mechanisms involved in producing the heartbeat.

16) Explain blood pressure in terms of systole and diastole. Describe the factors affecting blood pressure and blood pressure's role in homeostasis.

17) Examine the structure (molecular and cellular) of blood constituents and describe their function.

18) Explain how the anatomy of the respiratory system functions to provide oxygen and carbon dioxide transport mechanisms between the lungs and the circulatory system, considering capillary structures, red blood cell structures, diffusion, and affinity.

19) Explain the relationship between the integumentary, muscular, and circulatory systems in temperature homeostasis.

Core Idea: The Immune and Lymphatic systems provide protection and lipid transport.

20) Describe the relationship between the structure and function of the lymphatic system.

21) Differentiate between innate and adaptive immunity, identifying immune cells that play a role in each.

22) Analyze ABO and Rh blood groups as a basis for blood transfusion and infant incompatibility reactions.

23) Diagram the progression of lipid transport from the digestive system, through the lymphatic system, and into the cardiovascular circulation.

Core Idea: The Digestive system provides for absorption of raw materials that build and fuel the body's cells.

24) Model the sequential organization of the alimentary canal and its accessory organs in order to describe the physiological role of each.

25) Analyze gastrointestinal wall histology and explain the anatomical architecture that supports efficient absorption and transport of molecules into cardiovascular or lymphatic circulation.

26) Investigate the actions of major digestive enzymes and hormones and identify their sources.

27) Describe the role of the hepatic portal system in coupling the digestive and cardiovascular systems.

Core Idea: The Urinary system provides for waste excretion, osmotic homeostasis, electrolyte homeostasis, and pH homeostasis.

28) Model the sequential organization of the male and female urinary tracts in order to describe the physiological role of blood filtration and waste excretion from the body.

29) Identify the parts of a nephron and describe how they assist in homeostatic mechanisms through urine formation.

Core Idea: The Endocrine system, through hormones, regulates the functions of organs to support life processes.

30) Using a model, name and locate the major endocrine glands and identify additional organ tissues in the human body that produce hormones. Describe the hormones produced and their physiological effects on other body targets.

31) Describe the relationship between receptors and ligands and differentiate between steroid and nonsteroid hormones as ligands.

32) Explain, using examples, the mechanism of negative feedback in hormonal production and control.

Core Idea: The Nervous system, in response to stimuli, coordinates functions of other body systems to support life processes.

33) Anatomically distinguish between the central nervous system and the peripheral nervous system. Explain how their structures and locations are related to their physiological roles.

34) Model the cellular and subcellular structures of neurons and explain the molecular neurophysiology of membrane potentials and the conduction of information through synaptic transmission.

35) Identify and describe the types of sensory receptors found in the human body.

36) Compare and contrast the structures and functions of the somatic nervous system and the autonomic nervous system.

37) Model the major parts of the brain and spinal cord, relating each part to its source of sensory information and/or its primary target of regulation.

38) Explain the structures, functions, and limitations of the human sensory systems (senses): hearing, balance/proprioception, sight, touch, smell, and taste.

Core Idea: The Reproductive systems ensure the continuity of species through gametogenesis, fertilization, and embryogenesis.

39) Identify and describe the organs of the human male and female reproductive systems that provide the physiological functions of gametogenesis, fertilization, and embryogenesis.

40) Examine the microscopic structures of the human egg and sperm and explain how their structures relate to their functions.

41) Based on the secretion of hormones, identify the endocrine tissues of the reproductive system and describe their roles in regulation of secondary sex characteristics, the female menstrual cycle, pregnancy, fetal development, and parturition.

42) Trace the major events of human development from fertilization to birth, with a focus on the development of organs and functional organ systems.

HAP.ETS2: Links Among Engineering, Technology, Science, and Society

1) Research system disorders to communicate information on the known facts about the disorders and identify technology that has been developed to diagnose and/or treat the disorders.

PHYSICAL SCIENCE: COURSE OVERVIEW

These academic standards establish the core content for Physical Science courses taught in Tennessee high schools.

The major disciplinary core ideas utilized for Physical Science include:

Physical Science (PSCI)
Physical Sciences (PS)
Matter and Its Interactions • Structure and properties of matter • Chemical reactions • Nuclear process
Motion and Stability: Forces and Interactions • Forces and motion • Types of interactions • Stability and instability in physical systems
Energy • Definitions of energy • Conservation of energy and energy transfer • Relationship between energy and forces • Energy in chemical processes and everyday life
Waves and Their Applications in Technologies for Information Transfer • Wave properties • Electromagnetic radiation

Science and engineering practices are embedded in the content standards. These practices are established to meet the specific academic standards. Skills, such as pattern recognition, cause and effect, experimental design, scale and proportion, systems, structure and function, and stability, should be stressed through hands-on learning within the classroom.

Inquiry is the central action within science and engineering. The process of observation, hypothesis testing, and refinement/application of ideas should be continually incorporated within the content of this course and not taught in isolation. Inquiry activities should be appropriate for the students' abilities.

By using these academic standards, curriculum relating to this course should be developed by teachers, schools, and districts. Emphasis should be placed on critical thinking, problem solving and applications, and communication (written and verbal) of student learning. It is recommended that a minimum of 25%

of this course be devoted to hands-on learning. Equipment and materials for completion of these investigations should be available for implementation by small student groups.

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Physical Science standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

These academic standards should be used for the development of classroom and course-level assessments.

PHYSICAL SCIENCE: ACADEMIC STANDARDS

PSCI.PS1: Matter and Its Interactions

1) Using the kinetic molecular theory and heat flow considerations, explain the changes of state for solids, liquids, gases, and plasma.

2) Graphically represent and discuss the results of an investigation involving pressure, volume, and temperature of a gas.

3) Construct a graphical organizer for the major classifications of matter using composition and separation techniques.

4) Apply scientific principles and evidence to provide explanations about physical and chemical changes.

5) Trace the development of the modern atomic theory to describe atomic particle properties and position.

6) Characterize the difference between atoms of different isotopes of an element.

7) Use the periodic table as a model to predict the relative properties of elements.

8) Using the patterns of electrons in the outermost energy level, predict how elements may combine.

9) Use the periodic table as a model to predict the formulas of binary ionic compounds. Explain and use the naming conventions for binary ionic and molecular compounds.

10) Develop a model to illustrate the claim that atoms and mass are conserved during a chemical reaction (i.e., balancing chemical equations).

11) Use models to identify chemical reactions as synthesis, decomposition, single-replacement, and double-replacement. Given the reactants, use these models to predict the products of those chemical reactions.

12) Classify a substance as acidic, basic, or neutral by using pH tools and appropriate indicators.

13) Research and communicate explanations on how acid rain is created and its impact on the ecosystem.

14) Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

15) Communicate scientific and technical information about nuclear energy and radioactive isotopes with respect to their impact on society.

PSCI.PS2: Motion and Stability: Forces and Interactions

1) Use mathematical representations to show how various factors (e.g., position, time, direction of force) affect one-dimensional kinematics parameters (distance, displacement, speed, velocity, acceleration). Determine graphically the relationships among those one-dimensional kinematics parameters.

2) Algebraically solve problems involving constant velocity and constant acceleration in one-dimension.
3) Use free-body diagrams to illustrate the contact and non-contact forces acting on an object.

4) Plan and conduct an investigation to gather evidence and provide a mathematical explanation about the relationship between force, mass, and acceleration. Solve related problems using F=ma.

5) Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

6) Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on an object during a collision.

7) Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field.

PSCI.PS3: Energy

1) Identify and give examples of the various forms of energy (kinetic, gravitational potential, elastic potential) and solve mathematical problems regarding the work-energy theorem and power.

2) Plan and conduct an investigation to provide evidence that thermal energy will move as heat between objects of two different temperatures, resulting in a more uniform energy distribution (temperature) among the objects.

3) Design, build, and refine a device within design constraints that has a series of simple machines to transfer energy and/or do mechanical work.

4) Collect data and present your findings regarding the law of conservation of energy and the efficiency, mechanical advantage, and power of the refined device.

5) Investigate the relationships among kinetic, potential, and total energy within a closed system (the law of conservation of energy).

6) Determine the mathematical relationships among heat, mass, specific heat capacity, and temperature change using the equation $Q = mCp\Delta T$.

7) Demonstrate Ohm's Law through the design and construction of simple series and parallel circuits.

8) Plan and conduct an experiment using a controlled chemical reaction to transfer thermal energy and/or do mechanical work.

9) Demonstrate the impact of the starting amounts of reacting substances upon the energy released.

PSCI.PS4: Waves and Their Applications in Technologies for Information Transfer

1) Use scientific reasoning to compare and contrast the properties of transverse and longitudinal waves and give examples of each type.

2) Design/conduct an investigation and interpret gathered data to explain how mechanical waves transmit energy through a medium.

3) Develop and use mathematical models to represent the properties of waves including frequency, amplitude, wavelength, and speed.

4) Describe and communicate the similarities and differences across the electromagnetic spectrum. Research methods and devices used to measure these characteristics.

5) Research and communicate scientific explanations about how electromagnetic waves are used in modern technology to produce, transmit, receive, and store information. Examples include: medical imaging, cell phones, and wireless networks.

PHYSICAL WORLD CONCEPTS: COURSE OVERVIEW

These academic standards constitute the core content for Physical World Concepts taught in Tennessee high schools.

The major disciplinary core ideas utilized for Physical World Concepts include:

Physical World Concepts (PWC)
Physical Sciences (PS)
Matter and Its Interactions • Structure and properties of matter • Nuclear process
Motion and Stability: Forces and Interactions • Forces and motion • Types of interactions • Stability and instability in physical systems
Energy • Definitions of energy • Conservation of energy and energy transfer • Energy in chemical processes and everyday life
Waves and Their Applications in Technologies for Information Transfer • Wave properties • Electromagnetic radiation

The goal of Physical World Concepts is to provide a strong foundation for all students taking higher level science courses. This course ensures that students understand how the physical world functions. Physical World Concepts uses science, engineering practices, and inquiry to challenge students to work though scientific endeavors. The course provides the skills that accomplish the goals of critical thinking, group dynamics, curiosity, and the ability to generate high ordered questions.

These academic standards are integrated into a hands-on lab based course. It is strongly encouraged that 45% of the course be based on experimentation and data collection. This sets the stage for proper laboratory methodology in future academic courses.

Students pursuing STEM as a post-secondary major will have the necessary preparation for success in college work, through the exposure to the engineering design process and data collecting laboratory experiments.

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Physical World Concepts standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

These academic standards should be used in order to develop classroom and course-level assessments.

PHYSICAL WORLD CONCEPTS: ACADEMIC STANDARDS

PWC.PS1: Matter and Its Interactions

1) Using the Bohr model of an atom, describe the following features and components of an atom: protons, neutrons, electrons, mass, number and types of particles, structure, and organization.

2) Use the kinetic molecular theory to explain how molecular motion is related to internal energy, temperature, heat, phase change, and expansion and contraction.

3) Use data collected from a calorimeter to construct a phase diagram to explain both the constant temperature and linearly changing segments of a graph.

4) Describe three forms of radioactivity in terms of changes in atomic number and mass number in order to write balanced equations for the three forms of radioactive decay.

5) Create a model that illustrates the difference between nuclear fission and nuclear fusion in terms of transmutation.

6) Through experimental data collections, investigate the concept of half-life.

PWC.PS2: Motion and Stability: Forces and Interactions

1) Investigate, measure, calculate, and analyze the relationship among position, displacement, velocity, acceleration, and time.
2) Explore characteristics of rectilinear motion and create distance-time graphs and velocity-time graphs.

3) Explain how Newton's first law applies to objects at rest and objects moving at a constant velocity.

4) Using Newton's second law, analyze the relationship among the net force acting on a body, the mass of the body, and the resulting acceleration though mathematical and graphical methods.

5) Apply Newton's third law to identify the interacting forces between two bodies.

6) Understand that the two-dimensional movement of an object can be explained as a combination of its horizontal and vertical components of motion.

7) Analyze the general relationship between net force, acceleration, and motion for an object undergoing uniform circular motion.

8) Describe the nature and magnitude of frictional forces.

9) Quantify interactions between objects to show that the total momentum is conserved in both elastic collisions and inelastic collisions.

10) Determine the impulse required to produce a change in momentum.

11) Using the law of universal gravitation, predict how gravitational force will change when the distance between two masses changes or the mass of one object changes.

12) Distinguish between mass and weight using SI units.

13) Represent the force conditions that exist for a system in equilibrium.

14) Through the use of force diagrams, explain why objects float or sink in terms of force and density.

15) Experimentally investigate the buoyant force exerted on floating and submerged objects.

16) Demonstrate the effects of Bernoulli's principle on fluid motion.

PWC.PS3: Energy

1) Investigate the definitions of force, work, power, kinetic energy, and potential energy.

2) Analyze the characteristics of energy and conservation of energy including friction, gravitational potential energy, and kinetic energy.

3) Compare and contrast the following ways in which energy is stored in a system: mechanical, electrical, chemical, and nuclear.

4) Describe various ways in which energy is transferred from one system to another (mechanical contact, thermal conduction, and electromagnetic radiation).

5) Demonstrate how or explain that energy is conserved in an isolated system even if transformations occur within the system (i.e., chemical to electrical, electrical to mechanical).

6) Calculate quantitative relationships associated with the conservation of energy.

7) Describe various ways in which matter and energy interact.

8) Mathematically quantify the relationship among electrical potential, current, and resistance in an ohmic system.

9) Relate the first law of thermodynamics as an application of the law of conservation of energy.

10) Analyze the relationship between energy transfer and disorder in the universe (second law of thermodynamics).

PWC.PS4: Waves and Their Applications in Technologies for Information Transfer

1) Build a model of a wave that describes the following characteristics of longitudinal waves and transverse waves: wavelength, frequency, period, amplitude, and velocity.

2) Quantify the relationship among the frequency, wavelength, and the speed of a wave.

3) Compare and contrast the properties and the applications of mechanical and electromagnetic waves.

4) Explain the relationship between the wavelength of light absorbed or released by an atom or molecule and the transfer of a discrete amount of energy.

5) Experimentally explore the additive and subtractive properties associated with color formation.

6) Using real world application, explain the principle of the Doppler Effect.
7) Investigate reflection, refraction, diffraction, and interference of waves.

8) Explain what function sound resonance has in practical form.

9) Analyze the application of polarization.

PHYSICS: COURSE OVERVIEW

The Physics academic standards were written to establish the core content and practices for all schools in the state of Tennessee. The core and component ideas in the Physical Sciences section in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ides* were used to subdivide the Physics course content into four sections:

Physics (PHYS)
Physical Sciences (PS)
Matter and Its Interactions • Structure and properties of matter • Chemical reactions • Nuclear process
Motion and Stability: Forces and Interactions • Forces and motion • Types of interactions • Stability and instability in physical systems
Energy • Definitions of energy • Conservation of energy and energy transfer • Relationship between energy and forces • Energy in chemical processes and everyday life
Waves and Their Applications in Technologies for Information Transfer • Wave properties • Electromagnetic radiation • Information technologies and instrumentation

PS1: Matter and Its Interactions

Properties of matter give rise to fields and forces. Students should understand that there are only a few properties of matter at a fundamental level and that these properties (charge, mass, spin) give rise to the fields and forces that exist as we understand them.

PS2: Motion and Stability: Forces and Interactions

An understanding of the forces and interactions between objects is important for describing an object's motion and determining the stability in a system. Students should understand that forces between objects arise from four types of interactions (gravitational, electromagnetism, and strong and weak nuclear interactions) and that some physical systems are more stable than others.

PS3: Energy
The concept of the transfer of energy in or out of a system can be explained and predicted. Students should understand the conservation of energy, how it is stored and transferred, the relationship between forces and how they are related to energy, and how we use energy in our everyday life.

PS4: Waves and Their Applications in Technologies for Information Transfer
Optics is the study of the interaction of optical photons (within the human visible range) with matter. These standards encompass the speed of light in a vacuum and other media, as well as diffraction, refraction, and the interference properties of light.

Throughout the Physics course, the seven crosscutting concepts should be reinforced in the appropriate context both in the classroom and hands-on experimentation. These standards also incorporate the core and component ideas in engineering, technology, and applications of science (cited throughout the standards) and should be implemented in this course.

Although science is a body of content knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science, thus combining content knowledge with skill. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Physics standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

These standards were written to allow students to engage in scientific reasoning, critique, creative thinking, and applied learning through hands-on investigations.

These academic standards should be used in order to develop classroom and course-level assessments.

PHYSICS: ACADEMIC STANDARDS

PHYS.PS1: Matter and Its Interactions

1) Develop models to illustrate the changes in the composition of the nucleus of an atom and the energy released during the processes of fission, fusion, and radioactive decay.

2) Recognize and communicate examples from everyday life that use radioactive decay processes.

3) Investigate and evaluate the expression for calculating the percentage of a remaining atom ($N(t)=N0e-\lambda t$) using simulated models, calculations, and/or graphical representations. Define the half-life ($t1/2$) and decay constant λ. Perform an investigation on probability and calculate half-life from acquired data (does not require use of actual radioactive samples).

PHYS.PS2: Motion and Stability: Forces and Interactions

1) Investigate and evaluate the graphical and mathematical relationship (using either manual graphing or computers) of one-dimensional kinematic parameters (distance, displacement, speed, velocity, acceleration) with respect to an object's position, direction of motion, and time.

2) Algebraically solve problems involving constant velocity and constant acceleration in one-dimension.

3) Algebraically solve problems involving arc length, angular velocity, and angular acceleration. Relate quantities to tangential magnitudes of translational motion.

4) Use free-body diagrams to illustrate the contact and non-contact forces acting on an object. Use the diagrams in combination with graphical or component-based vector analysis and with Newton's first and second laws to predict the position of the object on which the forces act in a constant net force scenario.

5) Gather evidence to defend the claim of Newton's first law of motion by explaining the effect that balanced forces have upon objects that are stationary or are moving at constant velocity.

6) Using experimental evidence and investigations, determine that Newton’s second law of motion defines force as a change in momentum, $F = \Delta p/\Delta t$.

7) Plan, conduct, and analyze the results of a controlled investigation to explore the validity of Newton's second law of motion in a system subject to a net unbalanced force, $Fnet = ma$ or $Fnet = \Delta p/\Delta t$.

8) Use examples of forces between pairs of objects involving gravitation, electrostatic, friction, and normal forces to explain Newton's third law.

9) Use Newton's law of universal gravitation, $\boldsymbol{F} = G\frac{m_1 m_2}{\boldsymbol{r}^2}$, to calculate the gravitational forces, mass, or distance separating two objects with mass, given the information about the other quantities.

10) Describe and mathematically determine the electrostatic interaction between electrically charged particles using Coulomb's law, $\boldsymbol{F_e} = k_e\frac{q_1 q_2}{\boldsymbol{r}^2}$. Compare and contrast Coulomb's law and gravitational force, notably with respect to distance.
11) Develop and apply the impulse-momentum theorem along with scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on an object during a collision (e.g., helmet, seatbelt, parachute).

12) Use experimental evidence to demonstrate that air resistance is a velocity dependent drag force that leads to terminal velocity.

13) Develop a model to predict the range of a two-dimensional projectile based upon its starting height, initial velocity, and angle at which it was launched.

14) Plan and conduct an investigation to provide evidence that a constant force perpendicular to an object's motion is required for uniform circular motion (F = m v2 / r).

PHYS.PS3: Energy

1) Identify and calculate different types of energy and their transformations (thermal, kinetic, potential, including magnetic and electrical potential energies) from one form to another in a system.

2) Investigate conduction, convection, and radiation as a mechanism for the transfer of thermal energy.

3) Use the principle of energy conservation and mathematical representations to quantify the change in energy of one component of a system when the energy that flows in and out of the system and the change in energy of the other components is known.

4) Assess the validity of the law of conservation of linear momentum (p=mv) by planning and constructing a controlled scientific investigation involving two objects moving in one-dimension.

5) Construct an argument based on qualitative and quantitative evidence that relates the change in temperature of a substance to its mass and heat energy added or removed from a system.

6) Define power and solve problems involving the rate of energy production or consumption ($P = \Delta E/\Delta t$). Explain and predict changes in power consumption based on changes in energy demand or elapsed time. Investigate power consumption and power production systems in common use.

7) Investigate and evaluate the laws of thermodynamics and use them to describe internal energy, heat, and work.

8) Communicate scientific ideas to describe how forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space. Explain how energy is contained within the field and how the energy changes when the objects generating and interacting with the field change their relative positions.

9) Describe, compare, and diagrammatically represent both electric and magnetic fields. Qualitatively predict the motion of a charged particle in each type of field, but avoid situations where the two types of fields are combined in the same region of space. Restrict magnetic fields to those that are parallel or perpendicular to the path of a charged particle.

10) Develop a model (sketch, CAD drawing, etc.) of a resistor circuit or capacitor circuit and use it to illustrate the behavior of electrons, electrical charge, and energy transfer.

11) Investigate Ohm's law ($I=V/R$) by conducting an experiment to determine the relationships between current and voltage, current and resistance, and voltage and resistance.

12) Apply the law of conservation of energy and charge to assess the validity of Kirchhoff's loop and junction rules when algebraically solving problems involving multi-loop circuits.

13) Predict the energy stored by a capacitor and how charge flows among capacitors connected in series or parallel.

14) Recognize and communicate information about energy efficiency and/or inefficiency of machines used in everyday life.

15) Compare and contrast the process, design, and performance of numerous next-generation energy sources (hydropower, wind power, solar power, geothermal power, biomass power, etc.).

PHYS.PS4: Waves and Their Applications in Technologies for Information Transfer

1) Know wave parameters (i.e., velocity, period, amplitude, frequency, angular frequency) as well as how these quantities are defined in the cases of longitudinal and transverse waves.

2) Describe parameters of a medium that affect the propagation of a sound wave through it.

3) Understand that the reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of characteristics of specific wave parameters and parameters of the medium.

4) Communicate scientific and technical information about how the principle of superposition explains the resonance and harmonic phenomena in air columns and on strings and common sound devices.

5) Evaluate the characteristics of the electromagnetic spectrum by communicating the similarities and differences among the different bands. Research and determine methods and devices used to measure these characteristics.

6) Plan and conduct controlled scientific investigations to construct explanations of light's behavior (reflection, refraction, transmission, interference) including the use of ray diagrams.

7) Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model.

8) Obtain information to construct explanations on how waves are used to produce, transmit, and capture signals and store and interpret information.

9) Investigate how information is carried in optical systems and use Snell’s law to describe the properties of optical fibers.

SCIENTIFIC RESEARCH: COURSE OVERVIEW

The academic standards for Scientific Research establish the content knowledge and skills for Tennessee students necessary to prepare them for the rigorous levels of higher education and future job markets. The course provides students with a wealth of experiences for both science practices and content knowledge needed in an ever changing 21st century. The academic standards for Scientific Research are research-based, are supported by the National Research Council's *Framework for K-12 Science Education*, and establish the core ideas and practices of science and engineering that prepare students to use scientific thinking to examine and evaluate knowledge encountered throughout their lives.

The major disciplinary core ideas utilized for Scientific Research include:

Scientific Research (SCRE)
Engineering, Technology, and Applications of Science (ETS)
Engineering Design
Links Among Engineering, Technology, Science, and Society • Interdependence of science, engineering, and technology • Influence of engineering, technology, and science on society and the natural world
Applications of Science • Nature of science components • Theory development and revision • Science practices utilized in developing and conducting original scientific research • Practice of peer review • Communicating scientific findings

Although science is a body of knowledge consisting of theories that explain data, science is also a set of practices that use analysis and argumentation to establish, extend, and refine knowledge. The science and engineering practices are used as a means to learn science by doing science. These practices are not intended to be a sequence of steps nor are they intended to be taught as a separate, introductory unit for the course. By combining content knowledge with skill, students discover how scientific knowledge is acquired and applied to solve problems or advance scientific knowledge further. In addition, there are seven crosscutting concepts that are fundamental to the nature of science and thus stretch across all science disciplines. The Scientific Research standards have been constructed by explicitly integrating practices and crosscutting concepts, iteratively and in combination, within each core idea to provide students with a well-rounded education in science.

Tennessee's state mathematics and literacy standards are integrated within the science standards. Special attention has been given to science literacy through the use of the science and engineering practices. Students are required to gather information from reliable sources to construct evidence-based arguments. STEM integration is supported throughout the Scientific Research standards.

By the end of the Scientific Research Course, it is expected that all students should be able to demonstrate the skills and content knowledge emphasized in the following standards.

SCIENTIFIC RESEARCH: ACADEMIC STANDARDS

SCRE.ETS2: Links Among Engineering, Technology, Science, and Society

1) Explore the impact of technology on social, political, or economic systems.

2) Describe the dynamic interplay among engineering, technology, and applied science.

3) Identify the most appropriate scientific instruments and/or computer programs for different experiments and research, and learn to use, care for, and maintain them, gather data, and analyze results.

4) Engage in evidence-based arguments through the scientific method of investigation to understand the effective role that scientific discoveries played in the progression of humankind.

SCRE.ETS3: Applications of Science

1) Research and present information about the history of the development of a scientific theory. Articulate reasons for refinements and/or replacement of this theory over time.

2) Engage in argument from evidence supporting the statement that science is tentative.

3) Generate questions and engage in discussion regarding the role of ethics in scientific research and in decision making based on scientific information.

4) Make observations and ask questions about the natural world. Refine the questions such that they can be answered by way of scientific investigation.

5) Use online search engines to find sources of scientific information. Develop, share, and revise criteria for evaluating reliability of sources.

6) Obtain and communicate information regarding ethical research practices pertaining to humans and animals as well as information regarding proper permitting agencies and procedures.

7) Obtain and present information on research protocols including citation formats (APA, MLA, etc.), plagiarism, and copyright and patent laws.

8) Engage in the peer review process by giving and receiving detailed feedback throughout the process of planning and carrying out investigations.

9) Develop a research proposal including the following: a problem statement; purpose of research; significance of research; objectives; literature review (including both primary and secondary sources); materials and methods; detailed budget; data analysis procedures; and, references. Include a list of potential risks associated with the study and a detailed safety plan as appropriate for materials and methods. Revise the proposal based on feedback from teacher and peers.

10) Create a scientific journal and/or lab notebook for recording qualitative and quantitative data.

11) Carry out an original scientific investigation (experiment or study) after having received approval of a revised research proposal.

12) Select and use appropriate statistical procedures (descriptive statistics, t-tests, regression and correlation, chi-square, etc.) to analyze data. Use available calculators, spreadsheets, and statistical software programs.

13) Select and use appropriate data tables, graphs, and diagrams to represent data. Use mathematic and computational thinking to look for patterns in data.

14) Develop a conclusion based on data analysis and cite evidence to support the conclusion.

15) Use data to develop a model. Evaluate the effectiveness of the model by making and testing predictions.

16) Evaluate experimental results and identify possible sources of error or bias in scientific investigations (published research, original research, and research of peers).

17) Write a scientific paper based on original scientific research including the following or equivalent sections: abstract, introduction, literature review, materials and methods, results, conclusions, and literature cited.

18) Prepare and give a presentation based on original scientific research.

19) Prepare a poster based on original scientific research and participate in a poster session.

20) Submit research to scientific agencies as appropriate.

GUIDING DOCUMENTS

- National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press. http://www.nap.edu/catalog.php?record_id=13165#

State Standards Used in the Development and Writing

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Other Resources

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- Lerner, L. S., Goodenough, U., Lynch, J., Schwartz, M., & Schwartz, R. (2012). *The State of State Science Standards, 2012*. Thomas B. Fordham Institute. http://edexcellence.net/publications/the-state-of-state-science-standards-2012.html
- National Research Council. (2013). *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press. http://www.nextgenscience.org/
- Young, A.G. (2012, November). *Going Beyond Verbs to Cognitive Complexity*. Handout: *Cognitive Rigor Matrix*. Presented at the 10th Annual South Carolina Formative Assessment Conference, Myrtle Beach, SC. South Carolina Formative Assessment Conference. http://scformativeassessment.com/wp-content/uploads/2012/06/Cognitive-Rigor-Matrix.pdf
- Tisko, E. (Retrieved July, 2014). AP Chemistry Notes. http://www.unomaha.edu/tiskochem/APChem/