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.

- <u>Developing and using models</u> to develop explanations for phenomena, to go beyond the observable and make predictions or to test designs.
- <u>Planning and carrying out controlled investigations</u> 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.
- <u>Analyzing and interpreting data</u> 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.
- <u>Using mathematics and computational thinking</u> as tools to represent variables and their relationships in models, simulations, and data analysis in order to make and test predictions.
- <u>Constructing explanations and designing solutions</u> to explain phenomena or solve problems.
- <u>Engaging in argument from evidence</u> to identify strengths and weaknesses in a line of reasoning, to identify best explanations, to resolve problems, and to identify best solutions.
- <u>Obtaining, evaluating, and communicating information</u> from scientific texts in order to derive meaning, evaluate validity, and integrate information.

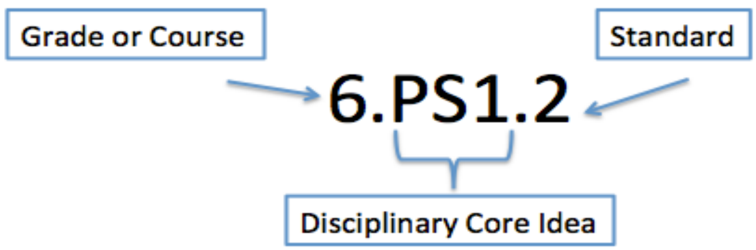
Engineering Technology and Science Practice Standards (ETS)

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.

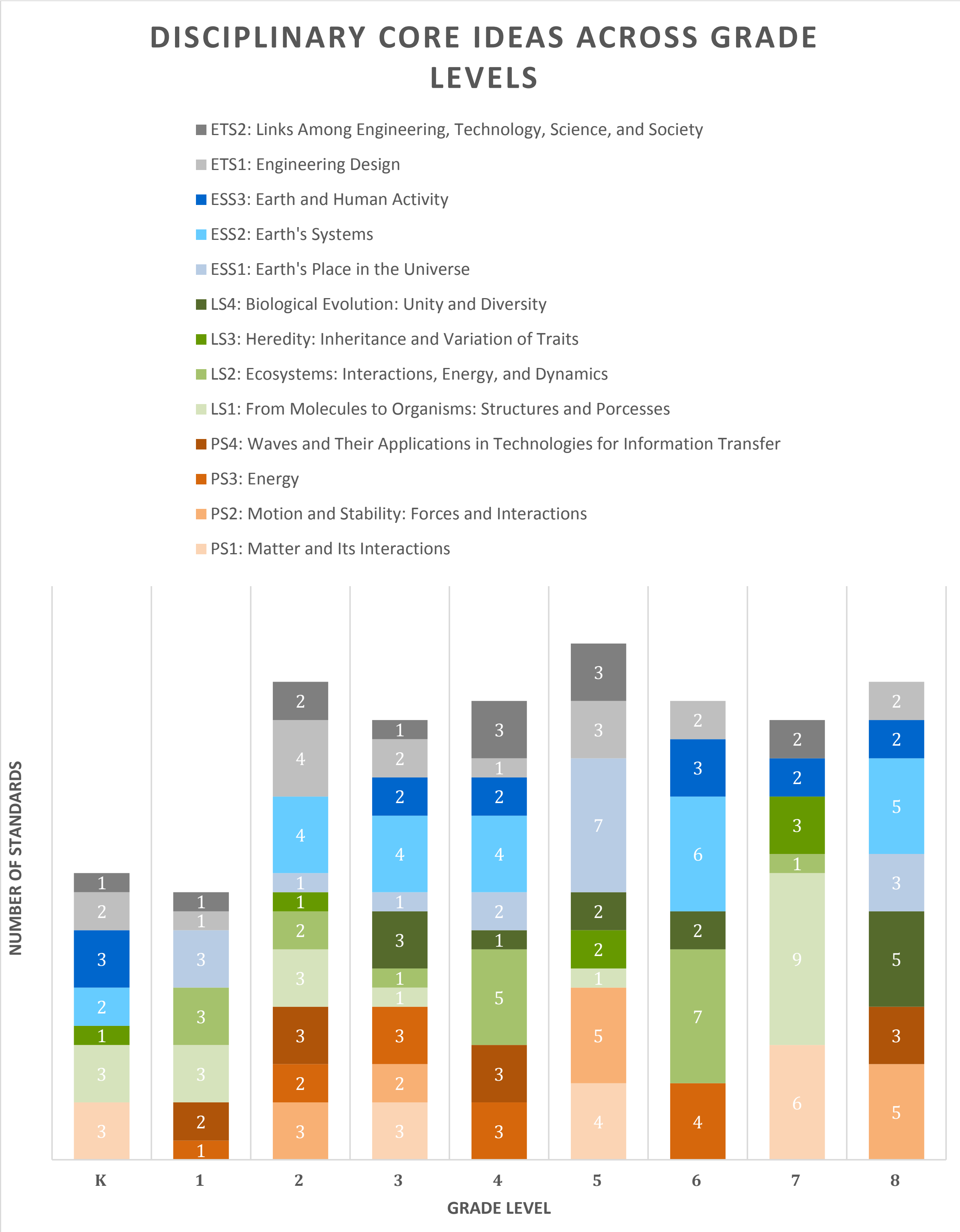
Grade Level Overviews

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
GRADE LEVEL
K
1
2
3
4
5
6
7
8

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.

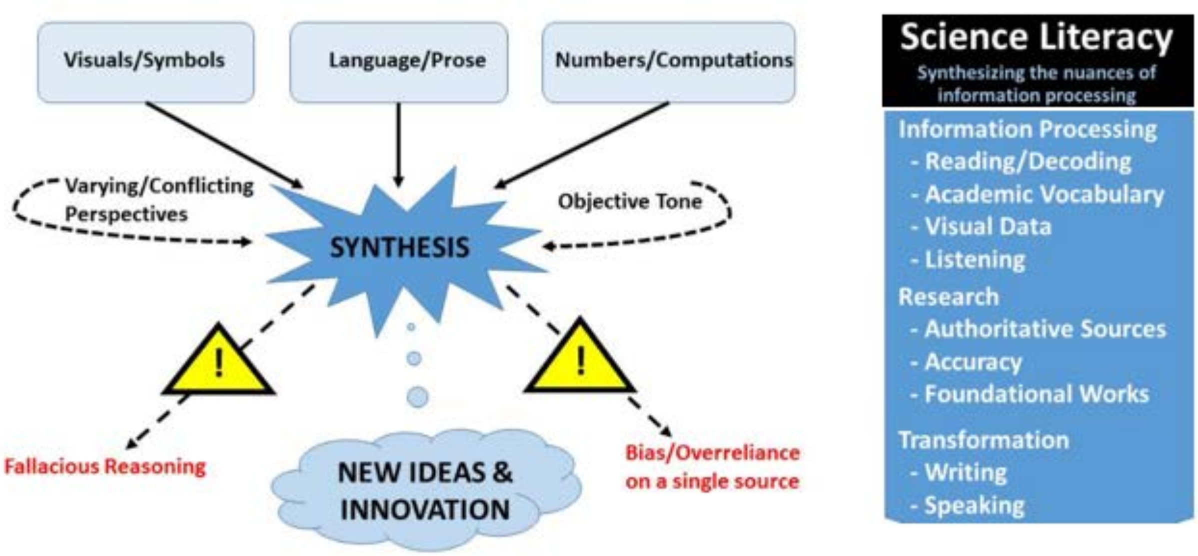
Effective communication within a scientific context requires students to apply literacy skills in reading, vocabulary, speaking and listening, and writing. Scientific information is presented in many formats with various tones and perspectives. Students must process and synthesize information effectively 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:

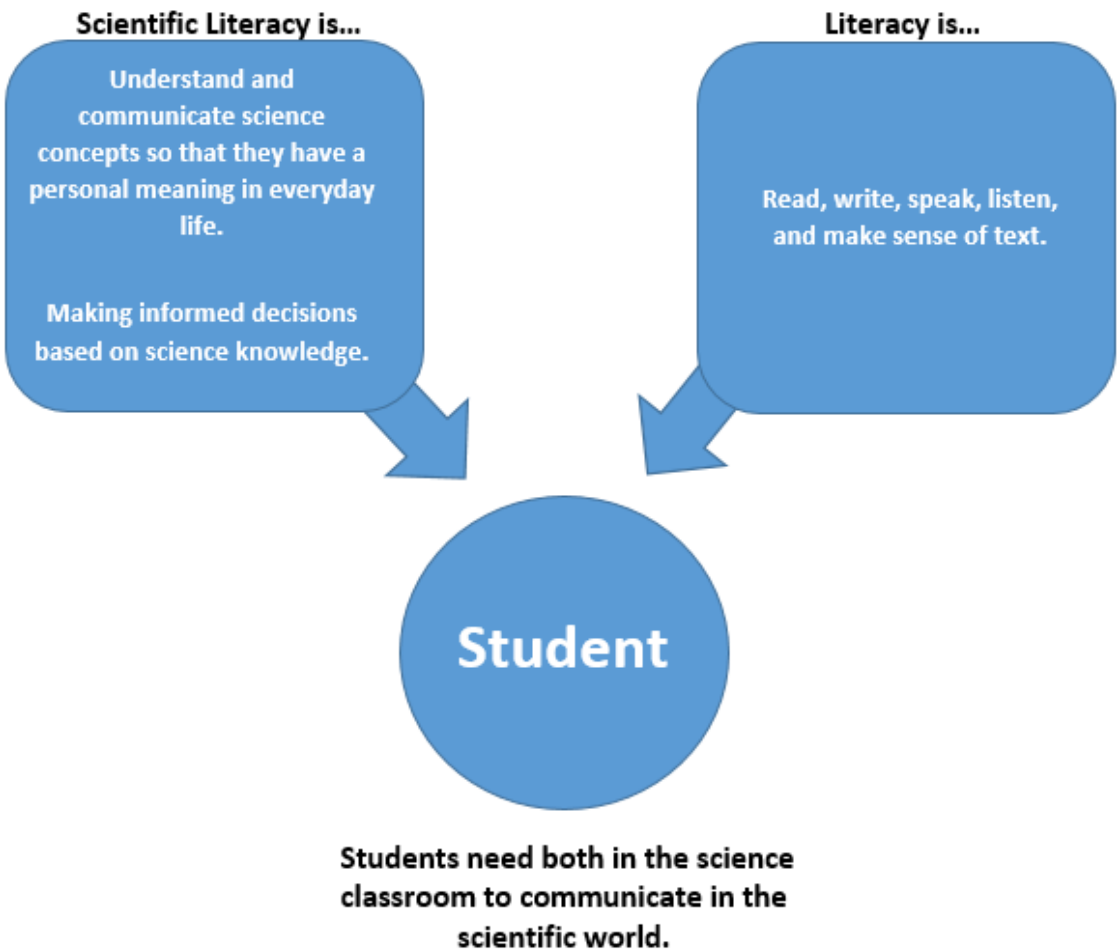
- Encourage the use of science and engineering practices to guide the development of literacy skills in science
- Provide a balance of appropriate sources beyond the textbook
- Provide opportunities for students to engage one another in critical discussion and argument surrounding specific content as 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



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.