CHAPTER 2

TIMSS 2027 Science Framework

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Overview

Science and technology constantly shape and reshape our daily lives: the food we eat, the air we breathe, our healthcare, communications, transportation, and more. Events like the COVID-19 pandemic and global climate change highlight the importance of scientific research in addressing problems with widespread societal impact. To understand and make informed decisions about these issues, we need to develop scientific literacy through science education that fosters analytical thinking and reasoning skills.

Scientific literacy empowers individuals to approach everyday situations and tackle important issues with critical thinking, problem-solving, and observational skills.[1] It aids them in distinguishing scientific knowledge from misinformation, and in making sound decisions that affect their own and others' health, society, the economy, and the environment.[2,3] For example, as new technologies emerge (e.g., artificial intelligence), scientific literacy can help individuals critically engage with these technologies, evaluating potential risks and benefits, reflecting on ethical implications, and participating in conversations about their societal influence.

In addition, there is an increased demand across the world for qualified professionals to pursue careers in science, technology, and engineering. Their knowledge and skills are needed to drive the innovation necessary to solve global societal and environmental problems, grow economies, and improve quality of life. To meet this demand, it is increasingly important that educators equip all students with an understanding of current scientific challenges and encourage more of them to consider advanced studies in science and related fields.

Science education in the primary grades capitalizes on young students' curiosity and starts them on a path of systematic inquiry about the world in which they live. As their understanding of science develops, students in the lower secondary grades can increasingly make informed decisions about themselves and their world so that, as adults, they can become informed and scientifically literate citizens[4] and decide whether to pursue a career in science and technology.

This philosophy towards science education forms the basis of this framework by defining the science knowledge, skills, and ways of thinking measured by the TIMSS assessment. The TIMSS 2027 Science Framework builds on TIMSS's 32-year history of assessments and describes the science measured in the fourth- and eighth-grade assessments. This chapter presents the assessment frameworks for the two TIMSS 2027 science assessments:

- TIMSS Science—Fourth Grade
- TIMSS Science—Eighth Grade

The TIMSS 2027 science frameworks are based on those underlying TIMSS 2023. However, there have been updates to reflect countries' evolving science curricula and learning goals as reported in the *TIMSS 2023 Encyclopedia*[5] and to reflect current best practices in science education and assessment. Namely, the TIMSS 2027 science frameworks incorporate the following changes from the TIMSS 2023 science frameworks:

- Environmental knowledge has been made a distinct subscale, drawing on specific topics from the biology and earth science content domains in the TIMSS science frameworks that measure students' understanding of environmental concepts.
- The topics of the fourth- and eighth-grade science frameworks align more clearly, showing the expected progression of students' scientific understanding between the grade levels.
- The percentage of items in the fourth-grade assessment devoted to knowing cognitive processes decreased to increase emphasis on engagement in science practices through investigations that require reasoning and applying knowledge and skills.
- The existing science practices are incorporated explicitly into the cognitive processes described within the cognitive domain of the science frameworks.

Domains of the TIMSS Science Frameworks

At each grade, the science assessment frameworks for TIMSS 2027 are organized around:

- *Content domains*, specifying the subject matter to be assessed
- *Cognitive domains*, specifying the thinking processes to be assessed[6]

The content and cognitive domains are described in more detail in the following sections.

TIMSS Science Content Domains

The TIMSS 2027 science frameworks define scientific literacy as including distinct content domains for both grades. The content domains differ for the fourth and eighth grades, reflecting the composition of each grade's curriculum. There is more emphasis on biology compared to physical science at the fourth grade than at the eighth grade. At the eighth grade, physics and chemistry are assessed as separate content domains and receive more emphasis than at the fourth grade, where they are assessed as one content domain (physical science). The earth science content domain has the same relative emphasis at both grades. Across all content domains, the objectives at the eighth grade are more sophisticated than at the fourth grade. To respond to TIMSS science items, students must have basic, grade-appropriate knowledge of scientific vocabulary, symbols, abbreviations, units, and scales.

While the TIMSS science assessment frameworks define distinct content domains, the nature of scientific knowledge is fundamentally interdisciplinary. There is overlap among scientific fields; therefore, knowledge from multiple disciplines is frequently required to answer scientific questions and solve problems. However, the technical distinction between content domains in TIMSS is necessary to facilitate an analysis that allows reporting an overall science achievement score and reporting achievement separately in content domains. For that reason, although some of the content objectives in the science frameworks incorporate concepts that cross multiple content domains, within the frameworks, these interdisciplinary concepts are assigned to one objective in one content domain. Compare, for example, the content objective, "*Describe how similarities and differences among living species and fossils provide evidence of the changes that occur in living things over time, and recognize that the degree of similarity of characteristics provides evidence of common ancestry*" with the objective, "*Recognize that some remains (fossils) of animals and plants that lived on Earth a long time ago are found in rocks and ice and make simple deductions about changes in Earth's surface from the location of these remains*." Both objectives require knowledge of the concept of fossils, but the first is classified as a biology topic related to diversity, adaptation, and natural selection, while the second is classified as an earth science topic, related to Earth's history. Therefore, items in TIMSS that ask about fossils contribute to either the biology or earth science content domain, depending on the specific knowledge that is asked of students.

Additionally, the following describes how science topics are organized within the TIMSS science content domains and how objectives are aligned with specific targets of measurement:

- Each content domain within the frameworks includes several major *topic areas*, and each topic area, in turn, includes one or more *topics*. Each topic is further described by specific *objectives* representing the students' expected factual knowledge and procedural knowledge or skills[7,8] assessed within each topic.[a]
- When interpreting the objectives, the following information is relevant: The verbs used in the objectives are intended to represent average, typical performances expected of a fourth- or eighth-grade student but are not intended to limit performances to a particular cognitive domain. Each objective can be assessed by drawing on any of the three cognitive domains (knowing, applying, and reasoning).
- Some objectives include additional parenthetical information. Illustrative examples appear after an "e.g.," such as in "*Recognize, compare, and contrast the life cycles of common animals (e.g., humans, frogs, butterflies)*." In other cases, the additional information is meant to restrict the scope of the objective to content appropriate for the students in the fourth or eighth grade. In that case, it appears after an "i.e.," such as in "*Recognize that matter can be changed from one state to another by heating or cooling; describe changes in the state of water (i.e., melting, freezing, evaporation, and condensation)*."

a The TIMSS 2027 science frameworks have an additional level of organization compared with the mathematics framework, which is organized into content domains, topic areas, and topics.

Across the fourth- and eighth-grade assessments, each content objective receives approximately equal weight regarding the number of score points. Exhibit 2.1 shows the target percentage of item score points in the assessment for each content domain for the TIMSS 2027 fourth- and eighth-grade assessments.

Exhibit 2.1: Target Percentages of the TIMSS 2027 Science Assessment Devoted to Each Content Domain at the Fourth and Eighth Grades

Fourth Grade

Content Domains	Percentages
Biology	45%
Physical Science	35%
Earth Science	20%

Eighth Grade

Content Domains	Percentages
Biology	35%
Chemistry	20%
Physics	25%
Earth Science	20%

Environmental Knowledge in TIMSS 2027

In TIMSS 2027, *environmental knowledge* is reported as an additional subscale comprising science items from the biology and earth science content domains. The objectives within the TIMSS 2027 Science content domains for the fourth and eighth grades selected to contribute to the environmental knowledge subscale have been marked with an asterisk. Approximately 25 percent of science items at both grades measure environmental knowledge while also belonging to the biology and earth science domains. A more detailed definition of environmental knowledge at both grades is provided in a later section.

TIMSS Science Cognitive Domains

Understanding science is not only having knowledge of science concepts and procedural knowledge of science skills, but also applying scientific ways of thinking and actively engaging in science practices.[9] One aspect cannot be separated from the other two; that is, knowledge is needed to engage in scientific thinking and practices, and vice versa. Current science curricula reflect standards for multiple aspects of science learning,[10,11,12] such as practices and knowledge. While the content domains in TIMSS cover scientific and procedural knowledge, the cognitive domains encompass the cognitive processes involved in scientific ways of thinking and using scientific practices to investigate the natural world. The content and cognitive domains define scientific knowledge and what students are asked to do with this knowledge.[13]

In the TIMSS assessments, three cognitive domains describe the thinking processes and science practices students are expected to engage in when encountering the science items developed for TIMSS 2027: *knowing*, *applying*, and *reasoning*. The three cognitive domains are the same at both grades, reflecting a progression from developing knowledge of scientific concepts to applying that knowledge and, finally, reasoning with conceptual understandings and evidence or data.[14,15] The first domain, knowing, covers the recollection of facts, concepts, and procedures that are necessary for a solid foundation in science. The second domain, applying, focuses on applying conceptual and procedural knowledge in various situations. The third domain, reasoning, involves using evidence and systematic thinking to draw conclusions, generate explanations, and understand the connections across scientific concepts, often in unfamiliar situations and complex contexts. While there is some hierarchy in the complexity of thinking processes across the three cognitive domains (from knowing to applying to reasoning),[16] applying and reasoning items can ask students to access these higher-order thinking skills using simple or more complex science facts. Therefore, each cognitive domain contains tasks representing a full range of item difficulty. Each cognitive domain also consists of a subset of *cognitive areas*, each defined by a verb that reflects the overarching thinking process. The three cognitive domains and their associated cognitive areas are described in more detail later in this chapter.

The three cognitive domains are used at both grades in the TIMSS science assessment; however, the target percentages for each domain vary between fourth and eighth grade. Exhibit 2.2 shows the target percentages in terms of the number of item score points for each of the three cognitive domains at the fourth and eighth grades. Previous TIMSS cycles included a higher percentage of score points devoted to knowing items at the fourth grade compared to TIMSS 2027. The TIMSS 2027 Science Framework decreases the percentage of score points devoted to knowing items at the fourth grade to emphasize the reasoning cognitive domain, which aligns with the cognitive demands of engaging in the scientific inquiry process. The percentage of score points for items that ask students to engage in reasoning is even higher at the eighth grade compared to the fourth grade.

Exhibit 2.2: Target Percentages of the TIMSS 2027 Science Assessment Devoted to Cognitive Domains at the Fourth and Eighth Grades

Cognitive Domains	Percentages by Grade	
	Fourth Grade	Eighth Grade
Knowing	35%	35%
Applying	40%	35%
Reasoning	25%	30%

Science Practices and Ways of Thinking in TIMSS 2027

Scientific knowledge is developed through scientific inquiry: rigorous investigation of the natural world using key science practices and scientific ways of thinking to answer questions and solve problems. Scientific ways of thinking include engaging in scientific reasoning processes[17] that utilize scientific concepts across disciplines, such as recognizing patterns and reasoning using cause and effect,[18] to support these processes. Science students must become proficient in these practices and ways of thinking to develop knowledge and understanding of scientific concepts. Engaging in science practices and ways of thinking also enables students to understand how the

scientific enterprise is conducted and, by extension, understand and appreciate the nature of science and scientific knowledge.[19,20] Increasing emphasis has been placed on scientific inquiry in many countries' current science curricula, standards, and frameworks.[21,22,23]

In the TIMSS 2027 science frameworks, the key science practices are embedded within the cognitive domains of reasoning and applying, and the practices are explicated with examples in the appropriate cognitive areas. The scientific ways of thinking are integrated into the cognitive domains implicitly, as they overlap with the defined cognitive processes. The practice of science and scientific thinking are strongly connected to the area of science under study and, therefore, cannot be assessed in isolation. Some items in the TIMSS 2027 science assessment at both the fourth and eighth grades will assess one or more of these important science practices together with content specified in the content domains. Students can engage in science practices and ways of thinking in the context of all the content domains.

The key science practices highlighted in the TIMSS science frameworks include skills that students use in a systematic way to conduct scientific investigations and that are applicable to all science disciplines. The following practices are distinguished in the TIMSS science assessment:

- **Practice 1**: Asking questions based on observations and theories and formulating hypotheses (embedded in the cognitive areas *Relate* and *Predict*).
- **Practice 2**: Designing investigations and generating evidence (embedded in the cognitive areas *Use Models* and *Design*).
- **Practice 3**: Working with data (embedded in the cognitive area *Interpret Information*).
- **Practice 4**: Answering research questions (embedded in the cognitive areas *Explain*, *Evaluate*, and *Draw Conclusions*).
- **Practice 5**: Making arguments from evidence (embedded in the cognitive areas *Justify* and *Generalize*).

While these practices are presented here as an ordered list, the complexity of scientific inquiry means that the process of employing them is, in reality, most often nonlinear and carried out iteratively.

While the cognitive domains and science practices are captured in all items in the TIMSS science assessments, problem-solving and inquiry tasks (PSIs) offer extended measurement of the science practices by including multiple steps of the inquiry process and higher-order cognitive skills across several items situated within more complex scenarios. PSIs comprise independent items individually assigned to one content and cognitive domain per item as defined in the remainder of this framework. However, PSIs establish a way to assess these domains more deeply and authentically, relying on a shared context across items to guide students through a wider range of cognitive processes and multiple steps of the inquiry process throughout the task.[24] This prepares students to engage with more complex scenarios and inquiry-based contexts than could be achieved in a single TIMSS item. Further information on characteristics of PSIs can be found in the TIMSS 2027 Guidelines for Developing PSIs.[25]

The next two sections of this chapter present the TIMSS 2027 science content domains for fourth and eighth grades, followed by a description of the cognitive domains which is applicable to both grades.

TIMSS 2027 Science Content Domains—Fourth Grade

Three major content domains define the science content for the TIMSS Science fourth-grade assessment: *biology*, *physical science*, and *earth science*.

Biology

The study of biology at the fourth grade provides students with an opportunity to capitalize on their innate curiosity and begin to understand the living world around them. In TIMSS 2027, biology is represented by six topic areas:

I. Characteristics and Life Processes of Organisms
II. Life Cycles, Reproduction, and Heredity
III. Diversity and Adaptation
IV. Ecosystems
V. Human Health
VI. Biological Investigations

By the fourth grade, students are expected to be building a base of knowledge about general characteristics of organisms, how they function, and how they interact with other organisms and with their environment. Students also should be familiar with basic science concepts related to life cycles, heredity, and human health that, in later grades, will lead to a more sophisticated understanding of how the human body functions. Students should know the basic features of biological investigations and the common materials or equipment they should use to make observations and collect data in biology contexts.

I. Characteristics and Life Processes of Organisms

1. Differences between living and nonliving things and what living things require to live:
   A. Recognize and describe differences between living and nonliving things (i.e., living things can reproduce, grow and develop, respond to stimuli, and die; and nonliving things cannot do all of these things).
   B. Identify what living things (i.e., plants and animals) require in order to live (i.e., air, food or light, water, and an environment in which to live).*
2. Physical and behavioral characteristics of major groups of living things:
   A. Compare and classify major groups of living things (i.e., animals and plants; mammals, birds, fish, reptiles, and insects) based on their physical and behavioral characteristics.
   B. Identify or provide examples of members of major groups of animals (i.e., mammals, birds, fish, reptiles, and insects).

3. Functions of major structures in living things:
   A. Relate major structures in animals to their functions (i.e., skin protects the body, bones support the body, lungs take in air, the heart circulates blood, the stomach digests food, and muscles move the body).
   B. Relate major structures in plants to their functions (i.e., roots absorb water and nutrients and anchor the plant; leaves make food; the stem keeps the plant upright and transports water, food, and nutrients; petals attract pollinators; flowers produce fruits and seeds; and seeds produce new plants).

4. Sustaining life and maintaining conditions under external changes:
   A. Recognize that plants produce their own food, using (sun)light, air, and water;* explain that animals eat plants or other animals to get the food they need.*
   B. Recognize and describe how animals respond to changes in external conditions (e.g., temperature and danger);* recognize and describe how the human body responds to changes in external conditions (e.g., temperature), and how it reacts to physical activity (e.g., exercise).

II. Life Cycles, Reproduction, and Heredity

1. Stages of life cycles and differences among the life cycles of common plants and animals:
   A. Identify stages of the life cycles of plants (i.e., germination, growth and development, pollination, flower and fruit production, and seed dispersal).
   B. Recognize, compare, and contrast the life cycles of common animals (e.g., humans, frogs, butterflies).

2. Inheritance and reproduction strategies:
   A. Recognize that plants and animals reproduce with individuals of their own kind but of the opposite sex to produce offspring with features that closely resemble those of the parents; distinguish between features of plants and animals that are inherited from their parents (e.g., number of petals, color of petals, eye color, hair color), and those that are not (e.g., some broken branches in a tree, length of human hair).
   B. Identify and describe different strategies of plants and animals that increase the number of offspring that survive (e.g., a plant producing many seeds, mammals caring for their young).

III. Diversity and Adaptation

1. Physical features and behaviors of living things that help them survive in their environment:
   A. Associate physical features of plants and animals with the environments in which they live and describe that they survive because of these features (e.g., a thick stem, a waxy coating, and a deep root help a plant survive in an environment with little water; the coloring of an animal helps camouflage it from predators).*
   B. Associate behaviors of animals with the environments in which they live and describe how these behaviors help them to survive (e.g., migration or hibernation helps an animal to stay alive when food is scarce).*

IV. Ecosystems

1. Common ecosystems:
   A. Relate common plants and animals (e.g., evergreen trees, frogs, lions) to common ecosystems (i.e., temperate forest, rainforest, desert, savannah, arctic, pond, river, and ocean).*

2. Relationships in ecosystems:
   A. Complete a linear model of a food chain using common plants and animals from common ecosystems (i.e., temperate forest, rainforest, desert, savannah, arctic, pond, river, and ocean) and describe the role of the organisms at each link in the food chain.*
   B. Identify predators and their prey.
   C. Recognize and explain that some living things in an ecosystem compete with others for resources (i.e., food, water, light, and space).*

3. The impact of humans on ecosystems:
   A. Provide examples of the effects of pollution on humans, plants, and animals (e.g., polluted air can cause lung diseases, animals might die from drinking polluted water).*
   B. Recognize that human behavior has negative and positive effects on populations in an ecosystem (e.g., shrinking habitats of polar bears due to global warming, polluting rivers by releasing waste, protection of elephant populations in national parks).*

V. Human Health

1. Transmission and prevention of diseases:
   A. Relate the transmission of common communicable diseases to human contact (e.g., touching, sneezing, coughing); identify or describe some methods of preventing disease transmission (e.g., vaccination, washing hands, keeping a physical distance from people who are sick, wearing a mask).

1. Ways of maintaining good health:
   A. Describe everyday behaviors that promote good physical and mental health (e.g., a balanced diet, exercising regularly, brushing teeth, getting enough sleep, taking time for relaxation, wearing sunscreen); identify common food sources included in a balanced diet (i.e., fruits and vegetables; grains and cereals; milk products; fish, meat, eggs, nuts, and beans).

VI. Biological Investigations

1. Features of and equipment used in biological investigations:
   A. Recognize basic features of a biological investigation (e.g., the fair setup of an experiment that investigates how light affects plant growth; the difference between observations of insects and inferences about their behavior); recognize how common materials or equipment (e.g., magnifying glass, tweezers) can be used during biological investigation.

Physical Science

At the fourth grade, students learn how many physical phenomena that they observe in their everyday lives can be explained through an understanding of physical science concepts. The topic areas for the physical science content domain at the fourth grade are:

I. Properties of Matter and Changes in Matter
II. Energy and Energy Transfer
III. Light and Sound
IV. Electricity and Magnetism
V. Motion and Forces
VI. Physical Science Investigations

Fourth-grade students should have an understanding of physical states of matter (solid, liquid, and gas), as well as common changes in the state of matter; this forms a foundation for the study of both chemistry and physics in the middle and upper grades. At this level, students should also know common forms and sources of energy and their practical uses, and understand basic concepts about light, sound, electricity, and magnetism. The study of forces and motion emphasizes an understanding of forces as they relate to movements students can observe, such as the effect of gravity or pushing and pulling. Students should know the basic features of investigations in physical science and the common materials or equipment they should use for measurement and collecting data during physical science investigations.

I. Properties of Matter and Changes in Matter

1. States of matter:
   A. Identify the three states of matter (i.e., solid, liquid, and gas) and describe their defining characteristics in terms of shape and volume; identify the state of water at a given temperature (i.e., ice, water, and water vapor).
   B. Recognize that matter can be changed from one state to another by heating or cooling; describe changes in the state of water (i.e., melting, freezing, evaporation, and condensation).
2. Physical properties as a basis for classifying matter:
   A. Compare and sort objects and materials on the basis of physical properties (i.e., weight/mass, volume, state of matter, ability to conduct heat or electricity, ability to float or sink in water, and ability to be attracted by a magnet). [Note: Students in the fourth grade are not expected to differentiate between mass and weight.]
   B. Identify properties of metals (i.e., conducting electricity and conducting heat) and relate these properties to uses of metals (e.g., a copper electrical wire, an iron cooking pot).

3. Physical and chemical changes observed in everyday life:
   A. Identify observable changes in materials that do not result in new materials with different properties (e.g., dissolving sugar in tea, crushing an aluminum can, freezing of water into ice); identify observable changes in materials that do result in new materials with different properties (e.g., decaying—such as food spoiling; burning; rusting).
   B. Describe examples of mixtures and how they can be physically separated (i.e., sifting, floating/sinking, filtration, evaporation, and magnetic attraction).
   C. Identify ways of increasing how quickly a solid material dissolves in a given amount of water (i.e., increasing the temperature, stirring, and breaking the solid into smaller pieces); distinguish between weak and strong concentrations of simple solutions (e.g., water sweetened with one versus two lumps of sugar).

II. Energy and Energy Transfer

1. Uses of energy in everyday life:
   A. Recognize that humans need energy for different purposes (e.g., heating, powering devices), and that this energy is provided in different forms (e.g., heat, electricity).
2. Heating and cooling:
   A. Describe that when a hot object is brought into contact with a cold object or surroundings, the temperature of the hot object decreases while the temperature of the cold object or surroundings increases.

III. Light and Sound

1. Light in everyday life:
   A. Relate common physical phenomena (i.e., shadows, reflections, and rainbows) to the behavior of light.
2. Sound in everyday life:
   A. Relate common physical phenomena (i.e., vibrating objects and echoes) to the production and behavior of sound.

IV. Electricity and Magnetism

1. Electricity and simple electrical devices:
   A. Recognize that electrical energy can be transformed into other forms of energy (e.g., heat, light, sound).
   B. Explain in the context of simple electrical devices (e.g., a flashlight) that electrical systems require a complete/unbroken electrical pathway; identify diagrams representing complete simple circuits.
2. Magnetic attraction and repulsion:
   A. Recognize that magnets have two poles, and that like poles repel and opposite poles attract.
   B. Recognize that magnets can be used to attract most metal objects.

V. Motion and Forces

1. Common forces and the motion of objects:
   A. Identify gravity as the force that draws objects to Earth.
   B. Recognize that pushing and pulling forces may cause an object to change its motion; compare the effects of these forces (i.e., pushes and pulls) of different strengths acting on an object in the same or opposite directions; and recognize that resistive forces (i.e., friction and air resistance) work against the direction of motion.
2. Simple machines:
   A. Recognize that simple machines (e.g., levers, pulleys, gears, ramps) help make motion easier (i.e., reduce the amount of force required or change the direction of the force).

VI. Physical Science Investigations

1. Features of and use of equipment in physical science investigations:
   A. Recognize basic features of an investigation in physical science (e.g., testable scientific questions related to dissolving sugar in water; the need for multiple measurements when comparing methods to avoid cooling of water in a mug).
   B. Recognize how common equipment (e.g., scale, stopwatch) can be used during an investigation in physical science.

Earth Science

Earth science is the study of Earth and its place in the Solar System, and at fourth grade focuses on the study of phenomena and processes that students can observe in their everyday lives. While there is no single picture of what constitutes an earth science curriculum that applies to all countries, the five topic areas included in this domain are generally considered to be important for students at the fourth grade to understand as they learn about the planet on which they live and its place in the Solar System:

I. Earth's Physical Features, Processes, and History
II. Earth's Atmosphere
III. Earth's Resources, their Use and Conservation
IV. Earth in the Solar System
V. Earth Science Investigations

At this level, students should have some general knowledge about the structure and physical characteristics of Earth's surface, and about the use of Earth's most important resources. Students also should be able to describe some of Earth's processes in terms of observable changes and understand the time frame over which such changes have occurred. Fourth-grade students should also demonstrate some understanding of Earth's place in the Solar System based on observations of patterns of change on Earth and in the sky. Students should know the equipment they can use during earth science investigations to collect data and make observations.

I. Earth's Physical Features, Processes, and History

1. Physical characteristics of the Earth's surface:
   A. Recognize that Earth's surface is made up of land and water in unequal proportions (more water than land) and is surrounded by air; describe where fresh and salt water are found.*

2. Earth's history:
   A. Recognize that wind and water change Earth's landscape (e.g., sand dunes, mountains, river valleys) and that some features of Earth's landscape (e.g., mountains, river valleys) result from changes that happen very slowly over a long time.
   B. Recognize that some remains (fossils) of animals and plants that lived on Earth a long time ago are found in rocks and ice and make simple deductions about changes in Earth's surface from the location of these remains.

II. Earth's Atmosphere

1. Weather and climates on Earth:
   A. Describe how weather (i.e., temperature, humidity, and precipitation in the form of rain or snow, clouds, and wind, all at a specific time) can vary from day to day and with geographic location.*
   B. Describe how average temperature and precipitation can change with the seasons and location; recognize that the average temperature on Earth has increased over the last century and identify some effects of this increase on Earth's physical characteristics (e.g., ocean levels have increased, ice caps have melted, rivers have dried up, deserts have grown bigger).*

III. Earth's Resources, their Use, and Conservation

1. Earth's resources:
   A. Recognize how some of Earth's resources (i.e., water, wind, soil, forests, minerals, and fossil fuels—coal, oil, natural gas) are used in everyday life (e.g., as an energy source, for building houses); recognize that some of these resources are nonrenewable (e.g., mined minerals, fossil fuels).*
   B. Explain the importance of using Earth's resources (i.e., water, wind, soil, forests, minerals, and fossil fuels—coal, oil, natural gas) responsibly.*

IV. Earth in the Solar System

1. Objects in the Solar System and their movements:
   A. Describe the Solar System as the Sun and the planets that revolve around it; recognize that the Earth has a moon that revolves around it, and that from Earth the Moon looks different at different times of the month.

2. Earth's motion and related patterns observed on Earth:
   A. Explain how day and night are related to Earth's daily rotation about its axis.
   B. Recognize that Earth revolves around the Sun in one year.

V. Earth Science Investigations

1. Use of equipment in earth science investigations:
   A. Recognize how common equipment (e.g., thermometer, compass, rain gauge) can be used during earth science investigations.

TIMSS 2027 Science Content Domains—Eighth Grade

Four major content domains define the science content for the TIMSS Science eighth-grade assessment: *biology*, *chemistry*, *physics*, and *earth science*.

Biology

At the eighth grade, students build on the foundational biological knowledge they learned in the primary grades and develop an understanding of many of the most important concepts in biology. The biology domain includes seven topic areas:

I. Characteristics and Life Processes of Organisms

II. Cells and their Functions

III. Life Cycles, Reproduction, and Heredity

IV. Diversity, Adaptation, and Natural Selection

V. Ecosystems

VI. Human Health

VII. Biological Investigations

Concepts learned in each of these topic areas are essential for preparing students for more advanced study. Therefore, eighth-grade students should have a foundational understanding of the relationship between structure and function across different levels of biological organization, and of energy flow in biological processes. Moreover, basic knowledge of the role of DNA in reproduction and heredity provides a foundation for more advanced study of molecular biology and molecular genetics. Learning the concepts of adaptation and natural selection provides a foundation for understanding evolution, and an understanding of processes and interactions in ecosystems is essential for students to begin to think about how to develop solutions to many environmental challenges. Developing a science-based understanding of the role of the immune system in human health enables students to improve the condition of their own and others' lives and is foundational to health-related and medical studies. Finally, students are expected to know and be able to explain the primary features of a sound investigation in biology, including how materials and equipment should be used to collect data and make observations in biological investigations.

I. Characteristics and Life Processes of Organisms

1. Differences among major taxonomic groups of organisms:
   A. Identify the defining characteristics that differentiate among major taxonomic groups (e.g., life cycles, respiratory systems, reproduction) of organisms (i.e., bacteria, fungi, plants, and animals; mammals, birds, fish, reptiles, amphibians, and insects).
   B. Recognize and categorize organisms that are examples of major taxonomic groups of organisms (i.e., bacteria, fungi, plants, and animals; mammals, birds, fish, reptiles, amphibians, and insects).
2. Structures and functions of major organ systems:
   A. Locate and identify major organ systems (i.e., respiratory, digestive, skeletal, and nervous systems), and their constituent organs (e.g., lungs, stomach, brain) in the human body.
   B. Compare and contrast major organs and major organ systems in humans and other vertebrates (e.g., lungs in humans compared with gills in fish).
   C. Explain the role of major organs and major organ systems in sustaining life (e.g., organs involved in circulation and respiration).
3. Physiological processes in plants and animals:
   A. Explain how animals respond to external and internal changes to maintain stable body conditions (e.g., increased heart rate during exercise, feeling thirsty when dehydrated, shivering in cold).
   B. Describe the function (i.e., to make sugar using energy) and basic process of photosynthesis (i.e., captures energy from light and requires carbon dioxide, water, and chlorophyll; produces glucose/sugar; and releases oxygen).*
   C. Describe the function (i.e., to release energy from sugar) and basic process of cellular respiration (i.e., requires oxygen and glucose/sugar; produces energy; and releases carbon dioxide and water).*

II. Cells and Their Functions

1. The structures and functions of cells:
   A. Explain that living things are made of cells and that these carry out life functions and reproduce by division.
   B. Identify major cell structures (i.e., cell wall, cell membrane, nucleus, cytoplasm, chloroplast, vacuole, and mitochondria) and describe the primary functions of these structures.
   C. Recognize that cell walls, chloroplasts, and vacuoles differentiate plant cells from animal cells.
   D. Explain that tissues, organs, and organ systems are formed from groups of cells with specialized structures and functions.

III. Life Cycles, Reproduction, and Heredity

1. Sexual reproduction and inheritance in plants and animals:
   A. Recognize that sexual reproduction involves the fertilization of an egg cell by a sperm cell to produce offspring that are similar but not identical to either parent; relate the inheritance of traits to organisms passing on genetic material to their offspring.
   B. Recognize that an organism's traits are encoded in its DNA; recognize that DNA is genetic information found in chromosomes located in the nucleus of each cell.
   C. Distinguish inherited characteristics from acquired or learned characteristics.

IV. Diversity, Adaptation, and Natural Selection

1. Variation as the basis for natural selection:
   A. Recognize that variations in physical and behavioral characteristics among individuals in a population give some individuals an advantage within the ecosystem to survive and pass on their characteristics to their offspring; recognize that in a changing environment the survival or extinction of a species is related to this reproductive success.
2. Evidence for changes in life on Earth over time:
   A. Draw conclusions about the relative lengths of time different organisms and groups of organisms have existed on Earth using fossil evidence.
   B. Describe how similarities and differences among living species and fossils provide evidence of the changes that occur in living things over time, and recognize that the degree of similarity of characteristics provides evidence of common ancestry.

V. Ecosystems

1. Natural, urban, and rural ecosystems:
   A. Contrast and compare natural, rural, and urban ecosystems with regard to the features of and the organisms within.*
2. The flow of energy in ecosystems:
   A. Describe the flow of energy in an ecosystem (i.e., energy flows from producers to consumers to decomposers, and only a small part of the energy is passed from one level to the next); construct and interpret energy pyramids.*
3. The cycling of water, oxygen, and carbon in ecosystems:
   A. Describe the role of living things in cycling water through an ecosystem (i.e., plants take in water from the soil and give off water through their leaves during transpiration; and animals take in water by drinking and release water during respiration and as waste).*
   B. Describe the role of living things in cycling oxygen and carbon through an ecosystem (i.e., plants take in carbon dioxide from the air and release oxygen into the air; and animals take in oxygen from the air and release carbon dioxide into the air).*

4. Relationships in ecosystems:
   A. Identify and provide examples of producers, consumers, and decomposers; construct and interpret food web diagrams.*
   B. Describe and provide examples of competition among populations or organisms in an ecosystem.*
   C. Describe and provide examples of predation in an ecosystem.*
   D. Describe and provide examples of mutualism and parasitism among populations of organisms in an ecosystem (e.g., birds or insects pollinating flowers, ticks living on deer or cattle).*
5. Factors affecting population size in an ecosystem:
   A. Identify factors that limit the size of a population (e.g., predators, food resources, water supply).*
   B. Predict how changes in an ecosystem (e.g., changes in the water supply, the introduction of a new population, migration) can affect the balance among populations.*
6. Human impact on ecosystems:
   A. Describe and provide examples of the effects of air, water, and soil pollution on humans, plants, and animals (e.g., water pollution can reduce plant and animal life in the water system).*
   B. Describe and explain how human behavior can have positive effects (e.g., replanting forests, reducing air and water pollution, protecting endangered species) or negative (e.g., allowing factories to release wastewater into water systems and pollutants into the air) effects on ecosystems.*

VI. Human Health

1. Causes, transmission, prevention of, and resistance to diseases:
   A. Describe causes, transmission, and prevention of common viral, bacterial, and parasite diseases (e.g., influenza, measles, HIV, COVID-19, tetanus, malaria).
   B. Describe the role of the body's immune system in resisting disease and promoting healing (e.g., antibodies in the blood help the body resist infection; and white blood cells fight infection).
   C. Recognize that vaccines can train the immune system to prevent both viral and bacterial diseases, while antibiotics can help the immune system to overcome bacterial infections; recognize that antibiotics may become less effective when bacteria change.

2. Ways of maintaining good health:
   A. Explain the importance of diet, exercise, and other lifestyle choices in maintaining mental and physical health and preventing illness (e.g., heart disease, high blood pressure, diabetes, skin cancer, lung cancer).
   B. Identify the dietary sources and roles of nutrients (i.e., vitamins, minerals, proteins, carbohydrates, and fats) in a healthy diet.

VII. Biological Investigations

1. Features of and equipment used in biological investigations:
   A. Identify and explain characteristics of a sound biological investigation (e.g., a researchable inquiry question about changes in an ecosystem, the difference between control and treatment variables in a biological investigation); identify how materials or equipment (e.g., a microscope) can be used during biological investigations.

Chemistry

At the eighth grade, students' study of chemistry extends beyond developing an understanding of everyday phenomena to learning the central concepts and principles that are needed for understanding practical applications of chemistry and undertaking later, more advanced study. The chemistry domain includes four topic areas:

I. Composition of Matter
II. Properties of Matter
III. Chemical Reactions
IV. Chemistry Investigations

The composition of matter topic area focuses on differentiating elements, compounds, and mixtures and understanding the particulate structure of matter. Included in this area also is the use of the periodic table as an organizing principle for the elements. At a more macroscopic level, the properties of matter topic area focuses on distinguishing between physical and chemical properties of matter and understanding the properties of mixtures, solutions, acids, and bases. The study of chemical reactions focuses on the characteristics of chemical changes, the conservation of matter during chemical changes, and the role of chemical bonds. Finally, the topic area on chemistry investigations includes the understanding of the primary features of a sound chemistry investigation and knowledge of the laboratory equipment used to make measurements during chemistry investigations.

I. Composition of Matter

1. Structure of atoms and molecules:
   A. Describe atoms as composed of subatomic particles (i.e., negatively charged electrons surrounding a nucleus containing positively charged protons and neutrons with no charge).
   B. Describe the structure of matter in terms of particles (i.e., atoms and molecules) and describe molecules as combinations of atoms (e.g., H_2O, O_2, CO_2).
   C. Recognize that a chemical bond results from the attraction between atoms in a compound and that the atoms' electrons are involved in this bonding.
2. Elements, compounds, and mixtures:
   A. Describe the differences among elements, compounds, and mixtures; differentiate between pure substances (i.e., elements and compounds) and mixtures (homogeneous and heterogeneous) on the basis of their formation and composition.
3. The periodic table of elements:
   A. Recognize that the periodic table is an arrangement of the elements; recognize and describe that the elements are arranged in order of the number of protons in the nuclei of the atoms of each element.
   B. Recognize that an element's properties (e.g., metal or nonmetal, reactivity) can be predicted from its location in the periodic table (i.e., row or period, and column or group/family) and that elements in the same group have some properties in common.

II. Properties of Matter

1. Physical and chemical properties as a basis for classifying matter and using materials:
   A. Distinguish between physical and chemical properties of matter.
   B. Classify common substances and materials according to physical properties (e.g., density, melting or boiling point, solubility, magnetic properties, electrical or thermal conductivity).
   C. Classify common substances and materials according to their chemical properties (e.g., reactivity, flammability) and relate uses of materials to their chemical properties.
2. Mixtures and solutions:
   A. Explain how physical methods can be used to separate mixtures into their components.
   B. Describe solutions in terms of substance(s) (i.e., solid, liquid, or gas solutes) dissolved in a solvent and relate the concentration of a solution to the amounts of solute and solvent present.
   C. Explain how temperature, stirring, and surface area in contact with the solvent affect the rate at which solutes dissolve.

3. Properties of acids and bases:
   A. Recognize everyday substances as acids or bases based on their properties (e.g., acidic foods usually have a sour taste, bases usually do not react with metals, bases feel slippery).
   B. Recognize that acids have a pH of less than 7, while bases have a pH of more than 7; recognize that acids and bases can neutralize each other; and recognize that both acids and bases react with indicators to produce different color changes.

III. Chemical Reactions

1. Characteristics of chemical reactions:
   A. Recognize that in a chemical reaction one or more pure substances/reactants transform into different pure substances/products, in contrast to a physical change; and describe evidence (i.e., temperature changes, gas production, precipitate formation, color change, or light emission) of a chemical reaction.
2. Matter and energy in chemical reactions:
   A. Recognize that matter is conserved during a chemical reaction and that all of the atoms present at the beginning of the reaction are present at the end of the reaction, but that they are rearranged to form new substances.
   B. Recognize chemical reactions that release energy/heat (e.g., burning) versus other reactions that require energy (e.g., the reaction of substances in a chemical cold pack).
   C. Recognize that chemical reactions occur at different rates and that the rate of reaction can be affected by changing the conditions under which the reaction is taking place (i.e., surface area, temperature, and concentration).

IV. Chemistry Investigations

1. Features of and equipment used in chemistry investigations:
   A. Identify and explain characteristics of a sound chemistry investigation (e.g., testable inquiry questions related to the rate of chemical reactions, the importance of changing only temperature between measurements of reaction rates).
   B. Recognize how materials and common lab equipment (e.g., balance, beaker, test tube) can be used appropriately in a chemistry investigation (e.g., how to work safely with chemical substances).

Physics

As in the chemistry domain, students' study of physics at the eighth grade extends beyond understanding the scientific basis of common everyday observations to learning many of the central physics concepts that are needed for understanding practical applications of physics or for undertaking advanced study later in their education. The physics domain includes six topic areas:

I. Physical States and Changes in Matter
II. Energy Transformation and Transfer
III. Light and Sound
IV. Electricity and Magnetism
V. Motion and Forces
VI. Physics Investigations

Eighth-grade students are expected to be able to describe processes involved in changes in the state of matter and relate states of matter to the distance and movement among particles. They should also be able to identify different forms of energy, describe simple energy transformations, apply the principle of conservation of total energy in practical situations, and understand the difference between thermal energy (heat) and temperature. Students at this level also are expected to know some basic properties of light and sound, relate these properties to observable phenomena, and solve practical problems involving the behavior of light and sound. In the topic area of electricity and magnetism, students should be familiar with the electrical conductivity of common materials, current flow in electric circuits, and the difference between simple series and parallel circuits. They also should be able to describe the properties and uses of permanent magnets and electromagnets. Students' understanding of motion and forces should include knowing the general types and characteristics of forces and how simple machines function. They should understand the concepts of pressure and density and be able to predict qualitative changes in motion based on the forces acting on an object. Students are expected to know and be able to explain the primary features of a sound investigation in physics, including how common equipment can be used to make measurements during physics investigations.

I. Physical States and Changes in Matter

1. Motion of particles in solids, liquids, and gases:
   A. Recognize that atoms and molecules in matter are in constant motion and recognize the differences in relative motion and distance between particles in solids, liquids, and gases; apply knowledge about the movement of and distance between atoms and molecules to explain the physical properties of solids, liquids, and gases (i.e., volume, shape, density, and compressibility).
   B. Relate changes in temperature to changes in the movement of and distance between particles for all states of matter; relate changes in temperature to changes in the volume and/or pressure of gases and to the expansion of liquids and solids.

2. Changes in states of matter:
   A. Describe changes of state (i.e., melting, freezing, evaporation, condensation, and sublimation) as resulting from an increase or decrease of thermal energy and recognize that temperature remains constant during melting, freezing, and boiling; explain that mass remains constant during changes of state.
   B. Relate the rate of change of state to physical factors (e.g., surface area, the temperature of the surroundings).

II. Energy Transformation and Transfer

1. Forms of energy and the conservation of energy:
   A. Identify different forms of energy (i.e., kinetic, potential, light, sound, electrical, thermal, and chemical).
   B. Describe the energy transformations that take place in common processes (e.g., combustion in an engine to move a car, photosynthesis, the production of hydroelectric power); recognize that the total energy of a closed system is conserved.
2. Thermal energy transfer:
   A. Relate the transfer of thermal energy from an object or an area at a higher temperature to one at a lower temperature to cooling and heating; recognize that hot objects cool off and cold objects warm up until they reach the same temperature as their surroundings.
   B. Relate the rate of transfer of thermal energy through a material to its thermal conductivity.

III. Light and Sound

1. Properties of light:
   A. Describe or identify basic properties of light (i.e., speed; transmission through different media; reflection, refraction, absorption; and splitting of white light into its component colors); relate the apparent color of objects to reflected or absorbed light.
   B. Solve practical problems involving the reflection of light from plane mirrors and the formation of shadows; interpret simple ray diagrams to identify the path of light.
2. Properties of sound:
   A. Describe or identify some basic properties of sound (i.e., sound is a wave phenomenon caused by vibrations; is characterized by loudness/amplitude and pitch/frequency; requires a medium for transmission; is reflected and absorbed by surfaces; and has a relative speed through different media, which is always slower than light) and relate this to common phenomena (e.g., echoes, hearing thunder after seeing lightning).

IV. Electricity and Magnetism

1. Conductors and the flow of electricity in electrical circuits:
   A. Identify materials as electrical conductors or insulators; identify electrical components or materials that can be used to complete circuits.
   B. Recognize complete and incomplete electrical pathways in simple, series, and parallel circuits and the difference between series and parallel circuits; interpret diagrams representing simple, series, and parallel circuits.

2. Properties and uses of permanent magnets and electromagnets:
   A. Relate properties of permanent magnets (i.e., two opposite poles, attraction/repulsion, and strength of the magnetic force varies with distance) to uses in everyday life (e.g., a directional compass).
   B. Describe the properties that are unique to electromagnets (i.e., the strength varies with current, number of coils, and type of metal in the core; the magnetic attraction can be turned on and off; and the poles can switch) and relate properties of electromagnets to uses in everyday life (e.g., doorbell, recycling factory).

V. Motion and Forces

1. Motion:
   A. Recognize the speed of an object as change in position/distance over time and acceleration as change in speed over time.

2. Common forces and their characteristics:
   A. Describe common mechanical forces (e.g., normal, friction, elastic, buoyant); recognize and describe weight as a force due to gravity.
   B. Recognize that forces have strength and direction; recognize that for every action force there is an equal and opposite reaction force.

3. Effects of forces:
   A. Describe the functioning of simple machines (e.g., levers, inclined planes, pulleys, gears).
   B. Explain floating and sinking in terms of density differences and the effect of buoyant force.
   C. Describe pressure in terms of force and area; describe effects related to pressure (e.g., water pressure increasing with depth, a balloon expanding when inflated).
   D. Predict qualitative changes in motion (speed and direction) of an object based on the forces acting on it; recognize and describe how resistive forces (i.e., friction and air resistance) affect motion (e.g., the contact area between surfaces can increase friction and impede motion).

VI. Physics Investigations

1. Features of and equipment used in physics investigations:
   A. Identify and explain characteristics of a sound physics investigation (e.g., asking answerable scientific questions about weather conditions, repeating measurements of temperature for accuracy).
   B. Recognize how common equipment (e.g., scale, ampere meter, spring balance) can be used appropriately in a physics investigation (e.g., working safely with glassware).

Earth Science

Topics covered in the teaching and learning of earth science draw on the fields of geology, astronomy, meteorology, hydrology, and oceanography, and are related to concepts in biology, chemistry, and physics. Although separate courses in earth science covering all these topics are not taught in all countries, it is expected that understandings related to earth science topic areas will have been included in a science curriculum covering the physical and life sciences or in separate courses such as geography and geology. The TIMSS 2027 Science Framework identifies the following topic areas that are universally considered to be important for students at the eighth grade to understand as they learn about the planet on which they live and its place in the universe:

I. Earth's Physical Features, Processes, and History
II. Earth's Atmosphere
III. Earth's Resources, Their Use, and Conservation
IV. Earth in the Solar System
V. Earth Science Investigations

Eighth-grade students are expected to have some general knowledge about the structure and physical features of Earth, including Earth's structural layers, and the atmosphere. Students also should have a conceptual understanding of processes, cycles, and patterns, including geological processes that have occurred over Earth's history, the water cycle, and patterns of weather and climate. Students should demonstrate knowledge of Earth's resources and their use and conservation and relate this knowledge to practical solutions to resource management issues. At this level, the study of Earth and the Solar System includes understanding how observable phenomena relate to the movements of Earth and the Moon, and describing the features of Earth, the Moon, and other planets. Students should also know what equipment is appropriate to use and how to use it to collect data during earth science investigations.

I. Earth's Physical Features, Processes, and History

1. Earth's structure:
   A. Describe the structure of the Earth (i.e., crust, mantle, inner core, and outer core) and the physical characteristics of these distinct parts.
   B. Describe the distribution of water on Earth in terms of its physical state (i.e., ice, water, and water vapor), and fresh versus salt water*; describe methods for ensuring that fresh water is available for human activities (i.e., desalination and purification).*

2. Geological processes:
   A. Describe the general processes involved in the rock cycle (i.e., the cooling of lava; weathering and erosion of rock to sediment; heat and pressure transforming sediment into rock; and melting of rock into magma).
   B. Identify or describe large scale changes to Earth's surface (e.g., mountain building), resulting from major geological events (i.e., glaciation; the movement of tectonic plates and subsequent earthquakes and volcanic eruptions; and the impact of an asteroid).
   C. Explain the formation of fossils and fossil fuels;* use evidence from the fossil record to explain how the environment has changed over long periods of time.

II. Earth's Atmosphere

1. Components of Earth's atmosphere and atmospheric conditions:
   A. Recognize that Earth's atmosphere is a mixture of gases; identify the relative abundance of its main components (i.e., nitrogen, oxygen, water vapor, and carbon dioxide).*
   B. Relate changes in atmospheric conditions (i.e., temperature and pressure) to changes in altitude.
2. Earth's water cycle:
   A. Describe the processes in Earth's water cycle (i.e., evaporation, condensation into clouds, cloud movement, precipitation, and water flow);* recognize the role of the water cycle in the renewal of fresh water on Earth's surface;* and recognize the Sun as the source of energy for the water cycle.
   B. Recognize that cloud formation and precipitation result from the condensation of water vapor due to the cooling of air, and that air cools when it rises (due to, e.g., warm surface, mountain ridges, colliding air masses).
3. Weather and climate:
   A. Distinguish between weather (i.e., day-to-day variations in temperature, humidity, different types of precipitation, clouds, and wind) and climate (i.e., long-term typical weather patterns in a geographic area).*
   B. Interpret climate data (i.e., graphs, tables, or maps) to identify climate types (e.g., tropical, arid, temperate, continental, polar); relate the climate and seasonal variations in average weather patterns to global and local factors (i.e., hemisphere, latitude, altitude, and geography).
4. Climate change:
   A. Identify or describe possible causes of global climate change (e.g., release of greenhouse gases by burning fossil fuel, volcanic eruptions).*
   B. Interpret data (i.e. graphs, tables, or maps) to identify evidence of local and global climate change (e.g., time series of global temperature, maps of decreasing ice caps).*

III. Earth's Resources, Their Use, and Conservation

1. Energy resources:
   A. Identify different energy sources that are used by humans and discuss their advantages and disadvantages (i.e., sunlight, wind, moving water, geothermal, wood and other biomass, nuclear, and fossil fuels: oil, coal, natural gas).*
2. Managing Earth's resources:
   A. Provide examples of Earth's renewable (e.g., forest, wind energy) and nonrenewable resources (e.g., mined minerals, fossil fuels).*
   B. Explain how common methods of land use (e.g., farming, logging, mining) can affect Earth's resources.*
   C. Explain the importance of the conservation of Earth's resources (e.g., water, soil, minerals), and describe and compare methods of conservation, including methods of waste management (i.e., reduce, reuse, and recycle).*

IV. Earth in the Solar System

1. Observable phenomena on Earth resulting from movements of Earth and the Moon:
   A. Describe the effects of the Earth's daily rotation around its axis (i.e., day and night and changing shadows) and describe how its annual revolution around the Sun, given the tilt of its axis, results in different seasons.
   B. Recognize that tides are caused by the gravitational pull of the Moon, and relate phases of the Moon and eclipses to the relative positions of Earth, the Moon, and the Sun.
2. The Sun, Earth, Moon, and planets:
   A. Recognize that the Sun is a star and provides light and heat to each member of the Solar System; explain that the Sun produces its own light, but that planets and moons are visible because of light reflected from the Sun.
   B. Interpret data (i.e., graphs, tables, or maps) to identify differences between features of Earth, the Moon, and other planets (e.g., presence and composition of an atmosphere, gravity, period of revolution and rotation); recognize that the force of gravity keeps planets and moons in their orbits.

V. Earth Science Investigations

1. Equipment used in earth science investigations:
   A. Recognize how common equipment (e.g., telescope, compass) can be used during earth science investigations.

Defining Environmental Knowledge in TIMSS 2027

TIMSS has historically included topics related to environmental knowledge in its fourth- and eighth-grade science assessments. The first international comparison of students' environmental knowledge was published in the *TIMSS 2019 Environmental Awareness Results*.[26] In 2023, environmental knowledge was complemented with environmental attitudes, as measured by the context questionnaires (see Chapter 3: TIMSS 2027 Contextual Framework and the supplement TIMSS 2023 Environmental Attitudes and Behaviors Framework).[27] Both environmental knowledge and attitudes are needed to develop environmental awareness, the first step to becoming environmentally literate. Therefore, knowledge and attitudes together shape the concept of environmental awareness.[28,29]

Building on the efforts and results of the environmental knowledge subscale from TIMSS 2019 and TIMSS 2023, TIMSS 2027 incorporates a more comprehensive and expanded definition of environmental knowledge in the science framework, providing a foundation for the environmental knowledge subscale for this and future cycles: Environmental knowledge is the understanding of how natural systems work, including the relationships between living organisms, their physical surroundings, and the impact of human activities on the environment. It is a comprehensive term that includes not only knowing scientific facts, but also mastering different types of environmental knowledge, such as systems knowledge, action-related knowledge, and effectiveness knowledge.[30,31] Thus, environmental knowledge includes both knowing scientific concepts and understanding how humans interact with the natural world, major environmental issues, and potential solutions.[32]

Content Objectives Contributing to Environmental Knowledge

The nature of environmental knowledge is particularly interdisciplinary:[33] many environmental concepts incorporate knowledge from multiple content domains. In TIMSS, environmental knowledge integrates concepts from the existing TIMSS content domains biology and earth science but is reported as an additional distinct subscale. More specifically, the knowledge that fourth- and eighth-grade students should have about the environment and environmental issues overlaps with some of the knowledge within the content domains of biology and earth science. Therefore, several content objectives in the TIMSS 2027 science frameworks are classified as measuring both the science content domain in which they are included, as well as environmental knowledge (i.e., specific items from biology and earth science are also assigned to the environmental knowledge subscale). For example, the objective about the impact of humans on the environment that is found within the biology content domain of the fourth-grade TIMSS 2027 science framework, "*Recognize that human behavior has negative and positive effects on populations in ecosystems (e.g., shrinking habitats of polar bears due to global warming, protection of elephant populations in national parks),*" is additionally classified to be used for the environmental knowledge subscale.

In general, the environmental knowledge subscale consists of the content objectives from biology and earth science that relate to climate change, Earth's resources, and ecosystem relationships. It also includes those biology and earth science objectives that directly improve understanding of these environmental concepts. For example, objectives on foundational topics, such as what living things need to survive and the formation of fossil fuels, are also included in the environmental knowledge subscale. In contrast, topics like cellular biology and Earth's structure are excluded as they do not relate directly nor are they foundational to interactions between natural systems and human activities. The content objectives from the TIMSS 2027 science frameworks for the fourth and eighth grades that have been selected to contribute to the environmental knowledge subscale have been marked with an asterisk.

For more information on environmental knowledge, see *Environmental Awareness in TIMSS 2023—Patterns in Achievement, Attitudes, Behaviors, and Contexts.*[34]

TIMSS 2027 Science Cognitive Domains—Fourth and Eighth Grades

For the fourth and eighth grades, each content domain includes items developed to address each of the three cognitive domains: knowing, applying and reasoning. The following sections further describe the thinking processes that define these cognitive domains. Each cognitive domain consists of a set of cognitive areas, each categorized by a verb that reflects the overarching thinking process and accompanied by a brief description. Beneath each description are expanded examples that illustrate the scope of the cognitive area, as well as how science practices and scientific ways of thinking are used in TIMSS items in each cognitive area. The examples that demonstrate specific science practices are followed by the number of the practice in parentheses.

Knowing

Items in this domain assess students' scientific knowledge (e.g., facts, relationships, processes, concepts). Accurate and broad-based factual and procedural knowledge forms a foundation that students can draw upon to successfully engage in the more complex cognitive activities essential to the scientific enterprise.

Recognize	Identify facts, relationships, objects, phenomena, and concepts; e.g.: • Identify the characteristics or properties of specific organisms, materials, and processes • Identify the appropriate uses for scientific equipment and procedures • Recognize an appropriate description of a phenomenon
Describe	Describe facts, relationships, objects, phenomena, and concepts; e.g.: • Describe properties, structures, or functions of organisms and materials • Describe relationships among organisms, materials, processes, and phenomena
Provide Examples	Provide or identify examples that meet given criteria; e.g.: • Identify examples of organisms, materials, or processes that possess certain specified characteristics • Illustrate statements of facts or concepts with appropriate examples

Applying

Items in this domain require students to engage in applying scientific knowledge (e.g., facts, relationships, processes, concepts, equipment, methods) in contexts likely to be common in the teaching and learning of science.

Compare/Contrast/ Classify	Identify or describe similarities and differences among groups; e.g.: • Make distinctions between groups of organisms, materials, or processes, based on characteristics or properties • Classify or sort objects, materials, organisms, and processes based on characteristics or properties
Relate	Relate scientific knowledge to a phenomenon or application; e.g.: • Recognize an observed or inferred property that explains the use of an object or material • Connect the behavior of organisms to the underlying scientific principle • Formulate questions that can be answered by investigation (Practice 1)
Use Models	Use a model to demonstrate knowledge of science concepts; e.g.: • Use a diagram to illustrate a process, cycle, relationship, or system • Use models to find solutions to science problems • Use models to generate data to answer a scientific question (Practice 2)
Interpret Information	Use knowledge of science concepts to interpret relevant, tabular, pictorial, and graphical information; e.g.: • Recognize patterns in information • Interpret a graph that represents a phenomenon • Interpret tabular data of a field observation (Practice 3)
Explain	Provide or identify an explanation for an observation or a phenomenon using a science concept or principle; e.g.: • Explain processes that produce changes that occur over time • Explain observations of organisms using structure and function • Explain observations using scientific knowledge (Practice 4)

Reasoning

Items in this domain require students to engage in reasoning to analyze data and other information, draw conclusions, and extend their understanding to new situations. Scientific reasoning also encompasses developing hypotheses as well as designing scientific models and investigations. In contrast to the more direct applications of science facts and concepts exemplified in the applying domain, items in the reasoning domain may involve less common or more complicated contexts or ask students to combine several facts, concepts, and processes. Answering such items can involve more than one approach or strategy.

Predict	Use scientific evidence and conceptual understanding to make predictions; e.g.: • Make predictions based on a given scenario or experimental design (Practice 1) • Formulate testable assumptions based on conceptual understanding and knowledge from experience, observation, and/or analysis of scientific information (Practice 1) • Make predictions about the effects of changes in biological or physical conditions or about the outcome of a dynamic situation
Design	Plan investigations or procedures appropriate for answering scientific questions or testing hypotheses; design models to illustrate processes; e.g.: • Develop models • Make decisions about the setup of an investigation (Practice 2) • Design a plan that applies scientific procedural principles to solve a problem (Practice 2)
Analyze/Synthesize	Answer questions that require consideration of a number of different factors or related concepts; e.g.: • Identify the elements of a scientific problem and combine them to answer a question • Combine information from multiple graphs to respond to a question • Apply information interpreted from a diagram alongside scientific understanding
Draw Conclusions	Draw appropriate conclusions that address questions or hypotheses; e.g.: • Make valid inferences on the basis of observations, evidence, and/or understanding of science concepts (Practice 4) • Answer research questions using understanding of cause and effect (Practice 4)
Evaluate	Evaluate models, results of investigations, and alternative explanations; e.g.: • Weigh advantages and disadvantages to make decisions about alternative processes and materials • Evaluate models in terms of their merits and limitations • Evaluate results of investigations with respect to sufficiency of data to support conclusions (Practice 4)
Justify	Use evidence and science understanding to support the reasonableness of explanations and conclusions; e.g.: • Defend solutions to problems • Support conclusions from investigations with experimental data (Practice 5)
Generalize	Make general conclusions that go beyond the experimental or given conditions; e.g.: • Apply conclusions of an experiment to new situations (Practice 5)

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