

CHAPTER 2

TIMSS 2015 Science Framework

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The development of an understanding of science is important for students in today's world if they are to become citizens who can make informed decisions about themselves and the world in which they live. Every day they will be faced with a barrage of information, and sifting fact from fiction and understanding the scientific basis of important social, economic, and environmental issues is possible only if they have the tools to accomplish this. Students in the early grades have a natural curiosity about the world and their place in it, thus it is appropriate for them to capitalize on this curiosity and start to learn science at a young age, especially because they can begin to use this knowledge to improve their own health and nutrition. Students' understanding of science should build throughout their schooling so that when, as adults, they are faced with decisions relating to such diverse issues as the treatment of diseases, climate change, and the applications of technology, they are able to act from a sound scientific basis. Across the world, there is an increased demand for those qualified to pursue the careers in science, technology, and engineering that drive the innovation and invention necessary for economic growth and improving the quality of life. To meet this demand, it is increasingly important to prepare significant proportions of students to enter advanced study in these areas.

This chapter contains the frameworks for the TIMSS science assessments at the fourth and eighth grades. In general, these frameworks are similar to those used in TIMSS 2011. However, there have been minor updates to particular topics to better reflect the curricula of the participating countries as reported in the *TIMSS 2011 Encyclopedia* (Mullis et al., 2012). Consideration also was given to current international research and initiatives in science and science education, such as the *Framework for K–12 Science Education* (National

Research Council, 2012) developed in the United States, the *Science (Primary and Lower Secondary) Syllabi* (Singapore Ministry of Education, 2007a; 2007b) used in Singapore, and the *Science Curriculum Guide (Primary 1–Secondary 3)* (Education Bureau, Hong Kong SAR, 2002b) used in Hong Kong.

At each grade, the science assessment framework for TIMSS 2015 is organized around two dimensions:

- Content dimension, specifying the subject matter to be assessed; and
- Cognitive dimension, specifying the thinking processes to be assessed.

Exhibit 7 shows the target percentage of testing time devoted to each content and cognitive domain for the TIMSS 2015 fourth and eighth grade science assessments.

Exhibit 7: Target Percentages of the TIMSS 2015 Science Assessment Devoted to Content and Cognitive Domains at the Fourth and Eighth Grades

Fourth Grade		
Content Domains	Percentages	
Life Science	45%	
Physical Science	35%	
Earth Science	20%	
Eighth Grade		
Content Domains	Percentages	
Biology	35%	
Chemistry	20%	
Physics	25%	
Earth Science	20%	
Cognitive Domains		
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	35%
Reasoning	20%	30%

The content domains differ for the fourth and eighth grades, reflecting the nature and difficulty of the science that is widely taught at each grade. There is more emphasis at the fourth grade on life science than its counterpart, biology, at the eighth grade. At the eighth grade, physics and chemistry are assessed as separate content domains and receive more emphasis than at fourth grade,

where they are assessed as one content domain (physical science). The three cognitive domains are the same at both grades, encompassing the range of cognitive processes involved in learning science concepts, and applying and reasoning with this knowledge, from the primary grades through the middle school years.

In 2015, TIMSS Science also will assess science practices. These practices include skills from daily life and school studies that students use in a systematic way to conduct scientific inquiry and that are fundamental to all science disciplines. Increasing emphasis has been placed on science practices and science inquiry in many countries' current science curricula, standards, and frameworks.

The TIMSS 2015 Science Framework takes the position that the understandings and skills required to undertake science practices cannot be assessed in isolation, but must be assessed in the context of one of the content domains, and draw upon the range of thinking processes specified in the cognitive domains. Therefore, some items in the TIMSS 2015 science assessment at both the fourth and eighth grades will assess one or more of these important science practices as well as content specified in the content domains and thinking processes specified in the cognitive domains.

The next two sections of this chapter present the TIMSS 2015 science content domains for fourth and eighth grades, followed by a description of the cognitive domains, which are applicable to both grades. The chapter concludes with a description of the science practices, which is a new section for TIMSS 2015.

Science Content Domains—Fourth Grade

Three major content domains define the science content for the TIMSS Science—Fourth Grade assessment: life science, physical science, and earth science. Exhibit 8 shows the target percentages for each of the three content domains in the TIMSS 2015 Science assessment.

Exhibit 8: Target Percentages of the TIMSS 2015 Science Assessment Devoted to Content Domains at the Fourth Grade

Fourth Grade Content Domains	Percentages
Life Science	45%
Physical Science	35%
Earth Science	20%

Each of these content domains includes one or more major topic areas, and each topic area in turn includes several topics. Each topic is further described by specific objectives that represent the learning that students should accomplish within each topic. Across the fourth grade assessment, each objective receives approximately equal weight in terms of time allocated to assessing the objective. The verbs used in the performance objectives are intended to represent typical performances expected of fourth graders, but are not intended to limit performances to a particular cognitive domain. Each performance objective can be assessed drawing on any of the three cognitive domains.

Life Science

The study of life science at the fourth grade provides students with an opportunity to capitalize on their innate curiosity and begin to understand the living world around them. At this level, life science is represented by five topic areas:

- Characteristics and life processes of organisms;
- Life cycles, reproduction, and heredity;
- Organisms, environment, and their interactions;
- Ecosystems; and
- Human health.

At this level, students should begin to build a base of knowledge about how organisms function and how they interact with other organisms and with their environment. They also should learn fundamental concepts in reproduction, heredity, and human health that in later grades will lead to a more sophisticated understanding of how the human body functions.

Life Science: Characteristics and Life Processes of Organisms

1. Differences between living and nonliving things and what living things require to live:
 - A. Recognize and describe the differences between living and non-living things (all living things reproduce, grow, develop, respond to stimuli, and die; and nonliving things do not).
 - B. Identify what living things require in order to live (they require air, food, water, and an environment in which to live).
2. Physical and behavioral characteristics of major groups of living things:

- A. Compare and contrast physical and behavioral characteristics that distinguish the following major groups of living things (insects, birds, mammals, fish, and flowering plants).
 - B. Identify or provide examples of living things belonging to the following major groups of living things: insects, birds, mammals, fish, and flowering plants.
 - C. Distinguish groups of animals with backbones from groups of animals without backbones.
3. Functions of major structures in living things:
- A. Relate major structures in animals to their functions (teeth break down food, the stomach digests food, bones support the body, lungs take in air, and the heart circulates blood).
 - B. Relate major structures in plants to their functions (roots absorb water and anchor the plant, leaves make food, the stem transports water and food, petals attract pollinators, flowers produce seeds, and seeds produce new plants).
4. Responses of living things to environmental conditions:
- A. Describe the effect of lack of water and lack of sunlight on plants.
 - B. Describe how different animals respond to high and low temperatures, and to danger.
 - C. Describe humans' bodily responses to exercise and to high and low temperatures.

Life Science: Life Cycles, Reproduction, and Heredity

1. Stages of life cycles and differences among the life cycles of common plants and animals:
- A. Recognize that plants and animals change in form as they go through different stages of their life cycles; identify the general stages of the life cycles of plants and animals (birth, growth and development, reproduction, and death).
 - B. Identify stages of the life cycles of plants (germination, growth and development, reproduction, and seed dispersal).
 - C. Recognize, compare, and contrast the life cycles of familiar plants and animals, such as trees, beans, humans, frogs, and butterflies.

2. Inheritance and reproduction strategies:
 - A. Recognize that plants and animals reproduce with their own kind to produce offspring with features that closely resemble those of the parents; recognize and explain that some features are the result of interactions with the environment, such as a plant's height being related to the amount of sunlight it receives, or a baby animal not gaining weight because it is not getting enough food.
 - B. Recognize and explain that some features that are inherited from parents help living things survive, such as the waxy coating on some plants' leaves helping the plants stay alive in dry climates or an animal's coloring helping it hide from predators.
 - C. Identify and describe different strategies that increase the numbers of offspring that survive, such as a plant producing many seeds or mammals caring for their young.

Life Science: Organisms, Environment, and their Interactions

1. Physical features or 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, such as a webbed foot belonging to an animal living in the water or a thick stem and spines belonging to a plant living in the desert.
 - B. Identify or describe examples of physical features or behaviors of plants and animals and how these help them survive in particular environments, such as hibernation helping an animal to stay alive when food is scarce or a deep root helping a plant survive in an environment with little water.

Life Science: Ecosystems

1. How plants and animals obtain energy:
 - A. Recognize that all plants and animals need food to provide energy for activity and raw materials for growth and repair.
 - B. Explain that plants need sunlight to make their food, while animals eat plants or other animals to get their food.

2. Relationships in a simple food chain:
 - A. Complete a model of a simple food chain using common plants and animals from familiar communities, such as a forest or a desert.
 - B. Describe the roles of living things at each link in a simple food chain (plants produce their own food, some animals eat plants, other animals eat the animals that eat plants).
3. Interactions among living things in a community:
 - A. Describe predator-prey relationships and identify common prey and their predators.
 - B. Recognize and explain that some living things in a community of living things compete with others for food or space.
4. The impact of humans on the environment:
 - A. Explain ways in which human behavior has positive and negative effects on the environment, including ways of preventing or reducing pollution.
 - B. Provide general descriptions and examples of the effects of pollution on humans, plants, animals, and their environments.

Life Science: Human Health

1. Transmission, symptoms, and prevention of communicable diseases:
 - A. Relate the transmission of common communicable diseases to human contact, such as touch, sneezing, coughing.
 - B. Recognize common signs of illness, such as high body temperature, coughing, and stomach ache.
 - C. Identify or explain some methods of preventing disease transmission, including washing hands and avoiding people who are sick.
2. Ways of maintaining good health:
 - A. Describe everyday behaviors that promote good health, such as eating a balanced diet, exercising regularly, washing hands, brushing teeth, getting enough sleep, or wearing sunscreen.
 - B. Identify common food sources included in a balanced diet, such as fruits, vegetables, or grains.

Physical Science

In the study of 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 fourth grade include the following:

- Classification and properties of matter and changes in matter;
- Forms of energy and energy transfer; and
- Forces and motion.

Fourth grade students should develop an understanding of physical states of matter, as well as common changes in the state and form of matter; this forms a foundation for the study of both chemistry and physics in the middle and upper grades. At this level, students also should 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 movements.

Physical Science: Classification and Properties of Matter and Changes in Matter

1. States of matter and characteristic differences of each state:
 - A. Identify three states of matter (solid, liquid, and gas).
 - B. Describe a solid as having a definite shape and volume, a liquid as having a definite volume but not a definite shape, and a gas as having neither a definite shape nor volume.
2. Physical properties as a basis for classifying matter:
 - A. Compare and sort objects and materials on the basis of physical properties, (weight/mass, volume, state of matter, ability to conduct heat or electricity, and whether an object floats or sinks in water).
 - B. Identify properties of metals (conducting electricity, conducting heat) and relate these properties to uses of metals.
 - C. Describe examples of mixtures and explain how they can be physically separated (using sifting, filtration, evaporation, or magnetic attraction).

Note: Students in the fourth grade are not expected to differentiate between mass and weight.

3. Magnetic attraction and repulsion:
 - A. Recognize that magnets have north and south poles and that like poles repel and opposite poles attract.
 - B. Recognize that magnets can be used to attract some other materials or objects.
4. Physical changes observed in everyday life:
 - A. Recognize that matter can be changed from one state to another by heating or cooling.
 - B. Describe changes in the state of water (melting, freezing, boiling, evaporation, and condensation) and relate these state changes to changes in temperature.
 - C. Identify ways of increasing how quickly material dissolves in a given amount of water (temperature, stirring, and surface area); and compare the concentrations of two solutions with different amounts of solute or solvent.
5. Chemical changes observed in everyday life:
 - A. Identify observable changes in materials that make new materials with different properties (decaying, burning, rusting, and cooking).

Physical Science: Forms of Energy and Energy Transfer

1. Common sources and uses of energy:
 - A. Identify sources of energy, such as the Sun, flowing water, wind, coal, oil, and gas, and understand that energy is needed to move objects and for heating and lighting.
2. Light and sound in everyday life:
 - A. Relate familiar physical phenomena (shadows, reflections, and rainbows) to the behavior of light.
 - B. Recognize that vibrating objects can make sound.
3. Heat transfer:
 - A. Recognize that heating an object can increase its temperature, and that hot objects can heat up cold objects.
 - B. Identify examples of common materials that easily conduct heat.

4. Electricity and simple electrical systems:
 - A. Identify objects and materials that conduct electricity.
 - B. Recognize that electrical energy in a circuit can be transformed into other forms of energy, such as light and sound.
 - C. Explain that simple electrical systems, such as a flashlight, require a complete (unbroken) electrical pathway.

Physical Science: Forces and Motion

1. Familiar forces and the motion of objects:
 - A. Identify gravity as the force that draws objects to Earth.
 - B. Recognize that forces (pushing and pulling) may cause an object to change its motion and compare the effects of forces of different strengths in the same or opposite direction acting on an object.

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 three topic areas included in this domain are generally considered to be important for students at the fourth grade to understand about the planet on which they live and its place in the solar system:

- Earth's structure, physical characteristics, and resources;
- Earth's processes and history; and
- Earth in the solar system.

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 about Earth's place in the solar system based on observations of patterns of change on Earth and in the sky.

Earth Science: Earth's Structure, Physical Characteristics, and Resources

1. Physical characteristics of the Earth system:
 - 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; and describe where fresh and salt water are found.
 - B. Recognize that wind and water change Earth's landscape.
2. Use of Earth's resources:
 - A. Identify some of Earth's resources that are used in everyday life such as water, wind, soil, forests, oil, natural gas, and minerals.
 - B. Explain the importance of using Earth's resources responsibly.
 - C. Explain how features of Earth's landscape, such as mountains, plains, deserts, rivers, lakes, and oceans, affect human activities, such as farming, irrigation, and land development.

Earth Science: Earth's Processes and History

1. Water on Earth and in the air:
 - A. Recognize that water in rivers or streams flows from mountains to oceans or lakes.
 - B. Recognize that water moves into and out of the air during common events such as cloud and dew formation, evaporation of puddles, and drying of wet clothes..
2. Daily, seasonal, and historical processes on Earth:
 - A. Describe how weather (variations in temperature, humidity, precipitation in the form of rain or snow, clouds, and wind) can vary with geographic location.
 - B. Describe how temperature and precipitation can change with the seasons and how these changes vary with location.
 - C. Recognize that some remains (fossils) of animals and plants that lived on Earth a long time ago are found in rocks and make simple deductions about changes in Earth's surface from the location of these remains.

Earth Science: Earth in the Solar System

1. Objects in the solar system and their movements:
 - A. Identify the Sun as the source of heat and light for the solar system; describe the solar system as the Sun and a group of planets (including Earth) that revolves around the Sun.
 - B. Recognize that the Moon revolves around Earth, and from Earth it 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, and provide evidence of this rotation from the changing appearance of shadows during the day.
 - B. Explain how seasons in the northern and southern hemispheres are related to Earth's annual movement around the Sun.

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. Exhibit 9 shows the target percentages for each of the four content domains in the TIMSS 2015 science assessment.

Exhibit 9: Target Percentages of the TIMSS 2015 Science Assessment Devoted to Content Domains at the Eighth Grade

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

Each of these content domains includes one or more major topic areas, and each topic area in turn includes several topics. Each topic is further described by specific objectives that represent the learning that students should accomplish within each topic. Across the eighth grade assessment, each objective receives approximately equal weight in terms of time allocated to assessing the objective. The verbs used in the performance objectives are intended to represent typical performances expected of fourth graders, but are not intended to limit performances to a particular cognitive domain. Each performance objective can be assessed drawing on each of the three cognitive domains.

Biology

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

- Characteristics and life processes of organisms;
- Cells and their functions;
- Life cycles, reproduction, and heredity;
- Diversity, adaptation, and natural selection;
- Ecosystems; and
- Human health.

Concepts learned in each of these topic areas are essential for preparing students for more advanced study. Eighth grade students should understand how structure relates to function in organisms and how organisms respond physiologically to changes in environmental conditions. They also should begin to build an understanding of cell structure and function and the processes of photosynthesis and cellular respiration. At this level, the study of 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. Finally, developing a science-based understanding of human health enables students to improve the condition of their lives and the lives of others.

Biology: 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 of organisms (plants vs. animals vs. fungi; mammals vs. birds vs. reptiles vs. fish vs. amphibians).
 - B. Recognize and categorize organisms that are examples of major taxonomic groups of organisms (plants vs. animals vs. fungi; mammals vs. birds vs. reptiles vs. fish vs. amphibians).

2. Structure and function of major organ systems:
 - A. Locate and identify major organs and the components of major organ systems in the human body.
 - B. Compare and contrast organs and organ systems in humans and other vertebrates.
 - C. Explain the role of organs and organ systems in sustaining life, such as those involved in circulation and respiration.
3. Physiological processes of animals:
 - A. Recognize responses of animals to external and internal changes that work to maintain stable body conditions, such as increased heart rate during exercise, feeling thirsty when dehydrated, feeling hungry when requiring energy.
 - B. Explain why it is important for most animals to maintain a relatively stable body temperature and how animals maintain a stable body temperature when the external temperature changes, such as sweating in heat and shivering in cold.

Biology: Cells and Their Functions

1. The structure and function of cells:
 - A. Explain that living things are made of cells that carry out life functions and undergo cell division.
 - B. Explain that tissues, organs, and organ systems are formed from groups of cells with specialized structures and functions.
 - C. Identify major cell structures (cell wall, cell membrane, nucleus, chloroplast, vacuole, and mitochondria) and describe the primary functions of these structures.
 - D. Recognize that cell walls and chloroplasts differentiate plant cells from animal cells.
2. The processes of photosynthesis and cellular respiration:
 - A. Describe or model the basic process of photosynthesis (requires light, carbon dioxide, water, and chlorophyll; produces food; and releases oxygen).
 - B. Describe or model the basic process of cellular respiration (requires oxygen and food, produces energy, and releases carbon dioxide and water).

Biology: Life Cycles, Reproduction, and Heredity

1. Life cycles and patterns of development:
 - A. Compare and contrast the life cycles and patterns of growth and development of different types of organisms (mammals, birds, amphibians, insects, and plants).
 - B. Describe factors that affect the growth of plants and animals.
2. 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.
 - B. Relate the inheritance of traits to organisms passing on genetic material to their offspring.
 - C. Distinguish inherited characteristics from acquired or learned characteristics.

Biology: 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 in surviving and passing on their characteristics to their offspring.
 - B. Relate species survival or extinction to reproductive success in a changing environment (natural selection).
2. Fossils as evidence for changes in life on Earth over time:
 - A. Draw conclusions about the relative length of time major 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 explain that the degree of similarity of characteristics provides evidence of common ancestry.

Biology: Ecosystems

1. The flow of energy in ecosystems:
 - A. Identify and provide examples of producers, consumers, and decomposers.

- B. Describe the flow of energy in an ecosystem (energy flows from producers to consumers and only part of the energy is passed from one level to the next).
 - C. Draw or interpret energy pyramids or food web diagrams.
- 2. The cycling of nutrients in ecosystems:
 - A. Describe the role of living things in the cycling of oxygen and carbon through an ecosystem.
 - B. Describe the role of living things in the cycling of water through an ecosystem.
 - 3. Interdependence of populations of organisms in an ecosystem:
 - A. Describe and provide examples of competition among populations of organisms in an ecosystem.
 - B. Describe and provide examples of predation in an ecosystem.
 - C. Describe and provide examples of symbiosis among populations or organisms in an ecosystem, such as birds or insects pollinating flowers, birds eating insects on deer or cattle, or a tapeworm living in human intestines.
 - 4. Factors affecting population size in an ecosystem:
 - A. Identify factors that limit population size, such as disease, predators, food resources, and drought.
 - B. Predict how changes in an ecosystem, such as water supply, population changes, or migration, can affect available resources, and thus the balance among populations.

Biology: Human Health

- 1. Causes, transmission, prevention, and resistance to diseases:
 - A. Describe causes, transmission, and prevention of common diseases, such as influenza, measles, malaria, and HIV.
 - B. Describe the role of the body's immune system in resisting disease and promoting healing.
- 2. The importance of diet, exercise, and lifestyle in maintaining health:
 - A. Explain the importance of diet, exercise, and lifestyle in maintaining health and preventing illness, such as heart disease, high blood pressure, diabetes, skin cancer, and lung cancer.

- B. Identify the dietary sources and role of nutrients in a healthy diet (vitamins, minerals, proteins, carbohydrates, and fats).

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 more advanced study. The chemistry domain includes three topic areas:

- Composition of matter;
- Properties of matter; and
- Chemical change.

The study of the composition of matter focuses on differentiating elements, compounds, and mixtures and understanding the particulate structure of matter. The properties of matter topic area focuses on distinguishing between physical and chemical properties of matter and understanding the properties of mixtures and solutions and acids and bases. The study of chemical change focuses on the characteristics of chemical changes, the conservation of matter during chemical changes, and an introduction to the structure and properties of chemical bonds.

Chemistry: Composition of Matter

1. Elements, compounds, and mixtures:
 - A. Identify examples of elements, compounds, and mixtures.
 - B. Differentiate between pure substances (elements and compounds) and mixtures (homogeneous and heterogeneous) on the basis of their formation and composition.
2. Structure of atoms and molecules:
 - A. Describe the structure of matter in terms of particles (atoms and molecules).
 - B. Describe atoms as composed of subatomic particles (electrons surrounding a nucleus containing protons and neutrons).
 - C. Describe molecules as combinations of atoms, such as H_2O , O_2 , and CO_2 .

Chemistry: Properties of Matter

1. Physical and chemical properties of matter:
 - A. Distinguish between physical and chemical properties of matter.
 - B. Relate uses of materials to their physical properties, such as melting point and boiling point, the ability to dissolve many substances, and thermal conductivity.
 - C. Relate uses of materials to their chemical properties, such as rusting and flammability.
2. Physical and chemical properties as a basis for classifying matter:
 - A. Classify substances according to physical properties that can be demonstrated or measured, such as density, melting or boiling point, solubility, magnetic properties, and electrical or thermal conductivity.
 - B. Classify substances according to their chemical properties (metals/nonmetals, and acids/bases).
3. 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) (solid, liquid, or gas solutes) dissolved in a solvent.
 - C. Relate the concentration of a solution to the amounts of solute and solvent present.
 - D. Explain how temperature, stirring, and surface area affect the rate at which solutes dissolve.
4. Properties of acids and bases:
 - A. Recognize everyday substances as acids or bases based on their properties (acids have a sour taste, react with metals and have pH less than 7; and bases usually have a bitter taste, feel slippery, do not react with metals, and have pH greater than 7).
 - B. Recognize that both acids and bases react with indicators to produce different color changes.
 - C. Recognize that acids and bases neutralize each other.

Chemistry: Chemical Change

1. Characteristics of chemical changes:
 - A. Differentiate chemical from physical changes in terms of the transformation (reaction) of one or more pure substances (reactants) into different pure substances (products).
 - B. Provide evidence (temperature changes, gas production, precipitate formation, color change, or light emission) that a chemical change has taken place.
 - C. Recognize that oxygen is needed in common oxidation reactions (combustion, rusting, and tarnishing) and relate these reactions to everyday activities such as burning wood or preserving metal objects.
2. Matter and energy in chemical changes:
 - A. Recognize that matter is conserved during a chemical change and that all of the atoms present at the beginning of the reaction are present at the end of the reaction, but they are rearranged to form new substances.
 - B. Recognize that some chemical reactions release energy (heat and/or light) while others absorb it and classify familiar chemical reactions (such as burning, neutralization, and cooking) as either releasing heat or absorbing heat.
3. Chemical bonds:
 - A. Recognize that a chemical bond is caused by the forces between atoms in a compound and that the atoms' electrons are involved in this bonding.

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 five topic areas:

- Physical states and changes in matter;
- Energy transformation and transfer;

- Light and sound;
- Electricity and magnetism; and
- Forces and motion.

Eighth grade students should 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 also should 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 concepts of 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 properties and uses of permanent magnets and electromagnets. Students' understanding of forces and motion should now extend to 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 define motion and predict qualitative changes in motion based on the forces acting on an object.

Physics: 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 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 (volume, shape, density, and compressibility).
 - B. Relate changes in temperature of a gas to changes in its volume and/or pressure and changes in the average speed of its particles; relate expansion of solids and liquids to temperature change in terms of the average spacing between particles.
2. Changes in states of matter:
 - A. Describe melting, freezing, boiling, evaporation, condensation, and sublimation as changes of state resulting from heating and cooling.

- B. Relate the rate of change of state to physical factors, such as surface area or the temperature of the surroundings.
- C. Recognize that temperature remains constant during freezing, melting, and boiling.
- D. Explain that mass remains constant during physical changes, such as change of state, dissolving solids, and thermal expansion.

Physics: Energy Transformation and Transfer

- 1. Forms of energy and the conservation of energy:
 - A. Identify different forms of energy (kinetic, potential, mechanical, light, sound, electrical, thermal, and chemical).
 - B. Describe common energy transformations, such as combustion in an engine to move a car, photosynthesis, or the production of hydroelectric power and recognize that the total energy of a closed system is conserved.
- 2. Heat transfer and thermal conductivity of materials:
 - A. Relate the transfer of energy from an object or an area at a higher temperature to one at a lower temperature to heating and cooling.
 - B. Recognize that hot objects cool off and cold objects warm up until they reach the same temperature as their surroundings.
 - C. Compare the relative thermal conductivity of different materials.

Physics: Light and Sound

- 1. Properties of light:
 - A. Describe or identify basic properties of light (transmission through different media; finite speed; reflection, refraction, absorption, and splitting of white light into its component colors).
 - B. Relate the apparent color of objects to reflected or absorbed light.
 - C. Solve practical problems involving the reflection of light from plane mirrors and the formation of shadows.
 - D. Interpret simple ray diagrams to identify the path of light and to locate images produced by lenses and mirrors (real images only).
- 2. Properties of sound:
 - A. Recognize that sound is a wave phenomenon and is characterized by loudness (amplitude) and pitch (frequency).

- B. Describe some basic properties of sound (the need for a medium for transmission, reflection and absorption by surfaces, and relative speed through different media).
- C. Relate common phenomena, such as echoes, to the properties of sound.

Physics: Electricity and Magnetism

- 1. Conductors and the flow of electricity in electrical circuits:
 - A. Classify materials as electrical conductors or insulators.
 - B. Identify diagrams representing complete circuits (series and parallel) and distinguish how the flow of electrical current differs between series and parallel circuits.
 - C. Describe factors that affect electrical currents in series or parallel circuits, such as number of batteries and/or bulbs.
- 2. Properties and uses of magnets and electromagnets:
 - A. Describe the properties of permanent magnets (attraction/repulsion; and strength of the magnetic force varies with distance).
 - B. Describe the properties that are unique to electromagnets (the strength varies with current and number of coils, the magnetic field can be turned on and off, and the poles can switch).
 - C. Describe uses of permanent magnets and electromagnets in everyday life, such as in a compass, doorbell, or recycling factory.

Physics: Forces and Motion

- 1. Common forces and their characteristics:
 - A. Describe common mechanical forces, including gravitational, normal, friction, elastic, and buoyant forces, and weight as a force due to gravity.
 - B. Recognize that forces have strength, direction, and a point of application.
 - C. Recognize that for every action force there is an equal and opposite reaction force.
- 2. Effects of forces:
 - A. Demonstrate basic knowledge of how simple machines function, such as levers and ramps.

- B. Explain pressure in terms of force and area.
 - C. Describe effects related to pressure, such as atmospheric pressure decreasing with altitude, water pressure increasing with depth, and evidence of gas pressure in balloons.
 - D. Explain floating and sinking in terms of density differences and the effect of buoyant force.
3. Motion and changes in motion:
- A. Define speed of an object as change in position (distance) over time and acceleration as change in speed over time.
 - B. Recognize that the motion of an object is determined by its speed and the direction in which it is moving.
 - C. Predict qualitative one-dimensional changes in motion (if any) of an object based on the forces acting on it.

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 of 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 2015 Science Framework identifies the following topic areas that are universally considered to be important for students at the eighth grade to understand about the planet on which they live and its place in the universe:

- Earth's structure and physical features;
- Earth's processes, cycles, and history;
- Earth's resources, their use and conservation; and
- Earth in the solar system and the universe.

Eighth grade students are expected to have some general knowledge about the structure and physical features of Earth, including Earth's structural layers, soils, and the atmosphere. Students also should build 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.

Earth Science: Earth's Structure and Physical Features

1. Physical characteristics of Earth's surface:
 - A. Describe the structure and physical characteristics of Earth's crust, mantle, and core as provided by observable phenomena, such as earthquakes and volcanoes.
 - B. Describe the characteristics, uses, and formation of soils.
 - C. Describe the distribution of water on Earth in terms of its physical state (ice, water, and water vapor), and fresh versus salt water.
 - D. Describe the movement of water from higher to lower elevation or below ground to above ground.
2. Components of Earth's atmosphere and atmospheric conditions:
 - A. Recognize that Earth's atmosphere is a mixture of gases; and identify the relative abundance of its main components (nitrogen, oxygen, water vapor, and carbon dioxide), and relate these components to everyday processes.
 - B. Relate changes in atmospheric conditions (temperature and pressure) to the altitude.

Earth Science: Earth's Processes, Cycles, and History

1. Geological processes during Earth's history:
 - A. Describe the general processes involved in the rock cycle, such as the cooling of lava, heat and pressure transforming sediment into rock, and weathering.
 - B. Identify or describe physical processes and major geological events that have occurred over millions of years, such as plate movement, volcanic activity, mountain building, and weathering.
 - C. Explain the formation of fossils and fossil fuels.

2. Earth's water cycle:
 - A. Diagram or describe the processes in Earth's water cycle (evaporation, condensation, and precipitation) and recognize the Sun as the source of energy for the water cycle.
 - B. Describe the role of cloud movement and water flow in the circulation and renewal of fresh water on Earth's surface.
3. Weather and climate:
 - A. Distinguish between weather (day-to-day variations in temperature, humidity, precipitation in the form of rain or snow, clouds, and wind) and climate (long-term typical weather patterns in a geographic area).
 - B. Interpret data or maps of weather patterns to identify different climates, and relate differences in weather to global and local factors.
 - C. Compare seasonal climates in relation to latitude, altitude, and geography.
 - D. Identify or describe possible causes and/or sources of evidence for climate changes, such as those that occur during ice ages or that are related to global warming.

Earth Science: Earth's Resources, Their Use and Conservation

1. Managing Earth's resources:
 - A. Provide examples of renewable and nonrenewable resources.
 - B. Discuss advantages and disadvantages of different energy sources.
 - C. Describe methods of conservation of resources and methods of waste management, such as recycling.
 - D. Propose ways that humans can address the negative effects of their activities on the environment.
2. Land and water use:
 - A. Explain how common methods of land use, such as farming, logging, or mining can affect land and water resources.
 - B. Explain the importance of water conservation, and describe how purification, desalinization, and irrigation ensure that fresh water is available for human activities.

Earth Science: Earth in the Solar System and the Universe

1. Observable phenomena on Earth resulting from movements of Earth and the Moon:
 - A. Distinguish between the effects of Earth's daily rotation about its axis and its annual revolution around the Sun, including how Earth's rotation and revolution relate to the appearance of constellations in the sky.
 - B. Explain that for most places away from the equator, the combination of the tilt of Earth's axis and its annual revolution around the Sun results in changing seasons.
 - C. 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. Features of Earth, the Moon, and other planets:
 - A. Compare and contrast certain physical features of Earth (atmosphere, temperature, water, distance from the Sun, period of revolution and rotation, and ability to support life) with the Moon and other planets.
 - B. Recognize that it is the force of gravity that keeps the planets and moons in orbits as well as pulls objects to Earth's surface.

Science Cognitive Domains—Fourth and Eighth Grades

The cognitive dimension is divided into three domains that describe the thinking processes students are expected to use when encountering the science items developed for TIMSS 2015. The first domain, knowing, addresses the student's ability to recall, recognize, and describe facts, concepts, and procedures that are necessary for a solid foundation in science. The second domain, applying, focuses on using this knowledge to generate explanations and solve practical problems. The third domain, reasoning, includes using evidence and science understanding to analyze, synthesize, and generalize, often in unfamiliar situations and complex contexts.

These three cognitive domains are used at both grades, however the target percentages for each domain vary between fourth and eighth grade in accordance with the increased cognitive ability, instruction, experience, and breadth and depth of understanding of students at the higher grade level.

The percentage of items that involve knowing is higher at the fourth grade while the percentage of items that ask students to engage in reasoning is higher at the eighth grade. While there is some hierarchy across the three domains (from knowing to applying to reasoning), each domain contains items representing a full range of difficulty. Exhibit 10 shows the target percentages for each of the three cognitive domains at the fourth and eighth grades.

Exhibit 10: Target Percentages of the TIMSS 2015 Science Assessment Devoted to Cognitive Domains at the Fourth and Eighth Grades

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	35%
Reasoning	20%	30%

For the fourth and eighth grades, each content domain includes items developed to address each of the three cognitive domains. For example, the life science content domain will include knowing, applying, and reasoning items, as will the other content domains. The following sections further describe the thinking processes that define the cognitive domains.

Knowing

Items in this domain assess students' knowledge of facts, relationships, processes, concepts, and equipment. Accurate and broad-based factual knowledge enables students to successfully engage in the more complex cognitive activities essential to the scientific enterprise.

Recall/Recognize	Identify or state facts, relationships, and concepts; identify the characteristics or properties of specific organisms, materials, and processes; identify the appropriate uses for scientific equipment and procedures; and recognize and use scientific vocabulary, symbols, abbreviations, units, and scales.
Describe	Describe or identify descriptions of properties, structures, and functions of organisms and materials, and relationships among organisms, materials, and processes and phenomena.
Provide Examples	Provide or identify examples of organisms, materials, and processes that possess certain specified characteristics; and clarify statements of facts or concepts with appropriate examples.

Applying

Items in this domain require students to engage in applying knowledge of facts, relationships, processes, concepts, equipment, and methods in contexts likely to be familiar in the teaching and learning of science.

Compare/Contrast/Classify	Identify or describe similarities and differences between groups of organisms, materials, or processes; and distinguish, classify, or sort individual objects, materials, organisms, and process based on given characteristic and properties.
Relate	Relate knowledge of an underlying science concept to an observed or inferred property, behavior, or use of objects, organisms, or materials.
Use Models	Use a diagram or other model to demonstrate knowledge of science concepts, to illustrate a process cycle relationship, or system, or to find solutions to science problems.
Interpret Information	Use knowledge of science concepts to interpret relevant textual, tabular, pictorial, and graphical information.
Explain	Provide or identify an explanation for an observation or a natural phenomenon using a science concept or principle.

Reasoning

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

Analyze	Identify the elements of a scientific problem and use relevant information, concepts, relationships, and data patterns to answer questions and solve problems.
Synthesize	Answer questions that require consideration of a number of different factors or related concepts.
Formulate Questions/ Hypothesize/Predict	Formulate questions that can be answered by investigation and predict results of an investigation given information about the design; formulate testable assumptions based on conceptual understanding and knowledge from experience, observation, and/or analysis of scientific information; and use evidence and conceptual understanding to make predictions about the effects of changes in biological or physical conditions.
Design Investigations	Plan investigations or procedures appropriate for answering scientific questions or testing hypotheses; and describe or recognize the characteristics of well-designed investigations in terms of variables to be measured and controlled and cause-and-effect relationships.
Evaluate	Evaluate alternative explanations; weigh advantages and disadvantages to make decisions about alternative processes and materials; and evaluate results of investigations with respect to sufficiency of data to support conclusions.
Draw Conclusions	Make valid inferences on the basis of observations, evidence, and/or understanding of science concepts; and draw appropriate conclusions that address questions or hypotheses, and demonstrate understanding of cause and effect.
Generalize	Make general conclusions that go beyond the experimental or given conditions; apply conclusions to new situations.
Justify	Use evidence and science understanding to support the reasonableness of explanations, solutions to problems, and conclusions from investigations.

Science Practices in TIMSS 2015

Scientists engage in scientific inquiry by following key science practices that enable them to understand the natural world and answer questions about it. Students of science must become proficient at these practices to develop an understanding of how the scientific enterprise is conducted. These practices include skills from daily life and school studies that students use in a systematic way to conduct scientific inquiry. The science practices are fundamental to all science disciplines. Five practices that are fundamental to scientific inquiry are represented in TIMSS 2015:

1. **Asking questions based on observations**—Scientific inquiry includes observations of phenomena in the natural world with unfamiliar characteristics or properties. These observations lead to questions, which are used to formulate testable hypotheses to help answer those questions.
2. **Generating evidence**—Testing hypotheses requires designing and executing systematic investigations and controlled experiments in order to generate evidence to support or refute the hypothesis. Scientists must relate their understanding of a science concept to a property that can be observed or measured in order to determine the evidence to be gathered, the equipment and procedures needed to collect the evidence, and the measurements to be recorded.
3. **Working with data**—Once the data are collected, scientists summarize it in various types of visual displays and describe or interpret patterns in the data and explore relationships between variables.
4. **Answering the research question**—Scientists use evidence from observations and investigations to answer questions and support or refute hypotheses.
5. **Making an argument from evidence**—Scientists use evidence together with science knowledge to construct explanations, justify and support the reasonableness of their explanations and conclusions, and extend their conclusions to new situations.

These science practices cannot be assessed in isolation, but must be assessed in the context of one of the science content domains, and by drawing upon the range of thinking processes specified in the cognitive domains. Therefore, some items in the TIMSS 2015 science assessment at both the fourth and eighth grades will assess one or more of these important science practices as well as content specified in the content domains and thinking processes specified in the cognitive domains.

