Overview

In today's world, some understanding of science is imperative if citizens are to make informed decisions about themselves and the world in which they live. Every day they are faced with a barrage of information, and sifting fact from fiction is possible only if they have the tools to accomplish this. It is important, therefore, to make certain that students leaving high school are equipped with a fundamental understanding of science such that the decisions they make are informed decisions. Students in the early grades have a natural curiosity about the world and their place in it, thus it is appropriate for them to start to learn the basics of science at a young age. This knowledge and understanding should be built upon throughout their schooling so that when as adults they are faced with making decisions that relate to such diverse issues as the treatment of diseases, global warming, and applications of technology, they are able to do so from a sound scientific basis.

In parallel with mathematics, the science assessment framework for TIMSS 2007 is organized around two dimensions, a content dimension specifying the domains or subject matter to be assessed within science (for example, biology, chemistry, physics, and Earth science at the eighth grade) and a cognitive dimension specifying the domains or thinking processes to be assessed (that is, knowing, applying, and reasoning). The cognitive domains describe the sets of behaviors expected of students as they engage with the science content.

The content and cognitive domains are the foundation of the TIMSS 2007 fourth- and eighth-grade assessments. The content domains differ for the fourth and eighth grades, reflecting the nature and difficulty of the science widely taught at each grade. There is more emphasis at the fourth grade on life science than on 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 cognitive framework, however, is the same for both grades, encompassing a range of cognitive processes involved in

learning science concepts and knowledge and engaging in scientific inquiry right through the primary and middle school years. Exhibit 6 shows the target percentages of testing time devoted to each science content and cognitive domain for the fourth- and eighth-grade assessments.

Exhibit 6: Target Percentages of the TIMSS 2007 Science Assessment Devoted to Content and Cognitive Domains at 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	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	30%
Applying	35%	35%
Reasoning	25%	35%

The content and cognitive domains for the science assessment are discussed in detail in the following sections. The content domains for the fourth grade are presented first, followed by those for the eighth grade. The cognitive domains, applicable to both grades, then follow. Example science items and tasks are presented in Appendix C.

Science Content Domains – Fourth Grade

While TIMSS recognizes that the organization of science curricula differs across countries, for the purposes of the TIMSS 2007 assessment at the fourth grade, three major domains covering most of the topics in the various countries' curricula were chosen to define the science content – life science, physical science, and Earth science. It should be noted that the topics included in these content domains may be taught in some countries in other subject areas, such as geography.

The content domains are shown in Exhibit 7 together with the target percentage devoted to each domain.

Exhibit 7: Target Percentages of the TIMSS 2007 Science Assessment Devoted to Content Domains at Fourth Grade

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

Each content domain has several main topic areas; each one is presented as a list of objectives covered in the science curriculum in the majority of participating countries. The sections below describe each of the science content domains, give an overview of the topic areas to be covered in each domain, and provide a set of assessment objectives for each topic area. These objectives are written in terms of behaviors to be elicited by items that exemplify the understandings and abilities expected of students at fourth grade.

Life Science

Life science includes understandings of the characteristics and life processes of living things, the relationships between them, and their

interaction with the environment. The topic areas for life science are as follows:

- Characteristics and life processes of living things
- Life cycles, reproduction, and heredity
- Interaction with the environment
- Ecosystems
- Human health

Knowledge of the characteristics and life processes of living things is fundamental to the study of life science. As such, students at fourth grade are expected to be able to distinguish between living and nonliving things, compare and contrast physical and behavioral characteristics of major groups of common organisms, and relate body structures of such organisms to their function.

Students are expected to know and be able to compare the life cycles of organisms such as the butterfly and frog; however in the areas of reproduction and heredity, knowledge is restricted to a very basic understanding that organisms of the same kind reproduce and that offspring closely resemble their parents.

Students are expected to be able to associate physical features and patterns of behavior of plants and animals with the environment in which they live and to provide examples of physical and behavioral characteristics that make some plants and animals better suited to particular environments. Students also should be able to demonstrate a rudimentary knowledge of bodily responses to outside conditions.

The study of ecosystems is essential to understanding the interdependence of living organisms and their relationship to the physical environment. Basic concepts related to ecosystems, including energy flow and the interaction of biotic and abiotic factors, are expected to be introduced in the primary school science curriculum. Students' understandings may be demonstrated through descriptions of specific relationships between plants and animals in common ecosystems. Some understanding of the ways in which human behavior can affect the

environment also is expected of fourth-grade students, especially in relation to pollution.

Finally, fourth-grade students are expected to have a rudimentary knowledge of human health, nutrition, and disease. They should demonstrate familiarity with common communicable diseases and also be able to relate diet and personal habits to their effect on health.

Life Science: Characteristics and Life Processes of Living Things

1. Distinguish between living and nonliving things; identify common features of living things (movement; basic needs for air, food, water; reproduction; growth; response to stimuli).
2. Compare and contrast physical and behavioral characteristics of major groups of organisms (e.g., insects, birds, mammals, plants), and identify or provide examples of plants and animals belonging to these groups.
3. Relate major body structures in humans and other organisms (plants and animals) to their functions (e.g., digestion takes place in the stomach, teeth break down food, bones support the body, lungs take in oxygen, plant roots absorb water, leaves make food).

Life Science: Life Cycles, Reproduction, and Heredity

1. Trace the general steps in the life cycle of plants (germination, growth and development, reproduction, seed dispersal) and animals (birth, growth and development, reproduction, and death); know and compare life cycles of familiar organisms (e.g., humans, butterflies, frogs, plants, mosquitoes).
2. Recognize that plants and animals reproduce with their own kind to produce offspring with features that closely resemble those of the parents.

Life Science: Interactions with the Environment

1. Associate physical features of plants and animals with the environments in which they live; identify or provide examples of certain physical or behavioral characteristics of plants and animals that make them better suited for survival in particular environments and explain why (e.g., color change, fur thickness, hibernation, migration).
2. Describe bodily actions in response to outside conditions (e.g., heat, cold, danger) and activities (e.g., exercise).

Life Science: Ecosystems

1. Understand that plants need the sun to make their own food, while animals consume plants or other animals as food; recognize that all plants and animals need food to provide energy for activity and raw material for growth and repair.
2. Explain relationships in a given community (e.g., forest, tidepool) based on simple food chains, using common plants and animals and predator-prey relationships.
3. Present ways in which human behavior can have a positive or a negative effect on environments; provide general descriptions and examples of the effects of pollution on humans, plants, animals, and their environments, and ways of preventing or reducing pollution.

Life Science: Human Health

1. Recognize ways that common communicable diseases (e.g., colds, influenza) are transmitted; identify signs of health or illness and some methods of preventing and treating illness.
2. Describe ways of maintaining good health, including the need for a balanced diet, identification of common food sources (e.g., fruits and vegetables, grains), and the effect of personal habits on health (e.g., regular exercise, nutritious diet).

Physical Science

Physical science includes concepts related to matter and energy, and covers topics in the areas of both chemistry and physics. Since students in fourth grade have only a beginning knowledge of chemistry, the framework places more emphasis on physics concepts. The topic areas for physical science are listed below:

- Classification and properties of matter
- Physical states and changes in matter
- Energy sources, heat, and temperature
- Light and sound
- Electricity and magnetism
- Forces and motion

In the area of classification of matter, fourth-grade students are expected to be able to compare or classify objects and materials on the basis of physical properties and relate these properties to their uses. Students also are expected to have a beginning practical knowledge of the formation of mixtures and water solutions.

In general, fourth-grade students have only a limited understanding of physical states and changes in matter from one form to another – solid, liquid, and gas. While general knowledge about changes of state is not expected, students are expected to know that water can exist in all three forms and can change from one form to another by being heated or cooled. Students also are expected to identify some changes in familiar materials that produce other materials with different properties, but they are not expected to know how these changes are related to chemical transformations.

Concepts related to energy sources, heat, and temperature are assessed at a very basic level. Students should be able to identify common energy sources and have some understanding of heat flow based on observable physical processes.

Students' understandings of light and sound will be assessed through identifying common light sources, relating familiar physical phenomena to the behavior of light, and recognizing that sound is produced by vibrations.

In the area of electricity and magnetism, students should have some notion of a complete electrical circuit and some practical knowledge of magnets and their uses. They also should have an intuitive grasp of the idea of forces as they relate to movement, such as gravity acting on falling objects and push/pull forces. Knowledge about the measurement of the weight of objects also may be assessed at the fourth grade in the context of floating objects or objects on a scale.

Physical Science: Classification and Properties of Matter

1. Compare or classify objects and materials on the basis of physical properties (e.g., weight/mass, shape, volume, color, hardness, texture, odor, taste, magnetic attraction).
2. Identify basic properties of metals and relate them to their use (e.g., conduct heat and electricity, are hard, are shiny, can be molded).
3. Identify or describe mixtures on the basis of physical appearance; demonstrate understanding that mixtures can be separated based on the observable properties of their parts (e.g., particle size, shape, color, magnetic attraction).
4. Identify properties and common uses of water (e.g., solvent, coolant, heat source) in each of its forms.
5. Give examples of materials that will dissolve in water and those that will not; and identify common conditions that increase the amount of material that will dissolve or the speed at which materials dissolve (hot water, stirring, small particles).

Physical Science: Physical States and Changes in Matter

1. Recognize that matter exists in three major states (solid, liquid, gas), and describe differences in the observable physical properties of solids, liquids, and gases in terms of shape and volume.
2. Recognize that matter can be changed from one state to another by heating or cooling, and describe these changes in familiar terms (melting, freezing, boiling, evaporation, condensation).
3. Identify some familiar changes in materials that produce other materials with different characteristics (e.g., decaying of animal or plant matter, burning, rusting, cooking).

Physical Science: Energy Sources, Heat, and Temperature

1. Identify common energy sources (e.g., wind, sun, electricity, burning fuel, moving water, food); know some practical uses of energy.
2. Recognize that heat flows from a hot object to a cold object and causes materials to change temperature and volume; identify common materials that conduct heat better than others; recognize the relationship between temperature measurements and how hot or cold an object is.

Physical Science: Light and Sound

1. Identify common sources of light (e.g., bulb, flame, sun); and relate familiar physical phenomena to the presence or absence and the behavior of light (e.g., appearance of rainbows; colors produced from soap bubbles; formation of shadows; visibility of objects; mirrors).
2. Recognize that sound is produced by vibrations.

Physical Science: Electricity and Magnetism

1. Identify a complete electrical circuit using batteries, bulbs, wires, and other common components that conduct electricity.
2. Recognize that magnets have north and south poles, that like poles repel and opposite poles attract, and that magnets can be used to attract some other materials or objects.

Physical Science: Forces and Motion

1. Identify familiar forces that cause objects to move (e.g., gravity acting on falling objects, push/pull forces).
2. Describe how the relative weight of objects can be determined using a balance; relate the weight* of different objects to their ability to float or sink.

* Knowledge of the concept of density and the distinction between weight and mass is not expected at grade 4. At this level, students may be assessed on their knowledge of flotation using objects of comparable size but different weight/mass.

Earth Science

Earth science is concerned with the study of Earth and its place in the solar system. While there is no single picture of what constitutes an Earth science curriculum that applies to all countries, the TIMSS 2007 framework identifies the following topic areas that are universally 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, cycles, and history
- Earth in the solar system

Fourth-grade students are expected to have some general knowledge about the structure and physical characteristics of Earth. They should know that solid Earth is composed of rocks, sand, and soil, and that most of Earth's surface is covered by water. Students also should have some understanding of the uses and conservation of Earth's

resources such as soil and fresh water. At this level, assessment of students' understandings of the atmosphere is limited to evidence for the presence of water and the importance of air for the survival of living things. They are also expected to know common features of Earth's landscape.

In the area of Earth's processes, cycles, and history, fourth-grade students are expected to be able to describe some of Earth's processes in terms of observable changes, including the movement of water, cloud formation, and changes in daily or seasonal weather conditions. Assessing the understanding of Earth's history is fairly limited at the fourth grade. However, students at this level should know that fossils found in rocks are the remains of plants and animals that lived a long time ago.

Fourth-grade students are expected to demonstrate some understandings about Earth's place in the solar system based on observations of changes in Earth and sky. In particular, they should be familiar with the motions of Earth, and relate daily changes on Earth to its rotation on its axis and relationship to the sun. They also should be able to draw or describe the phases of the moon.

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

1. Identify substances that make up Earth's surface (e.g., rocks, minerals, sand, and soil), know where these substances are found, and compare some of their physical characteristics and uses.
2. Recognize that most of Earth's surface is covered with water; describe the locations and types of water found on Earth (e.g., salt water in oceans, fresh water in lakes, rivers, clouds, snow, ice caps, icebergs).
3. Provide evidence for the existence and nature of air, including the fact that air contains water (e.g., cloud formation, dew drops, evaporation of ponds), provide or identify examples of the uses of air, and recognize the importance of air for supporting life.

4. Identify or describe common features of Earth's landscape (e.g., mountains, plains, rivers, deserts) and relate them to human use (e.g., farming, irrigation, land development).
5. Identify some of Earth's resources that are used in everyday life (e.g., water, soil, wood, minerals, fuel, food); explain the importance of using these resources wisely.

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

1. Describe the movement of water on Earth's surface (e.g., flowing in rivers or streams from mountains to oceans or lakes); relate the formation of clouds and rain or snow to a change of state of water.
2. Describe changes in weather conditions from day to day or over the seasons in terms of temperature, precipitation (rain or snow), clouds, and wind.
3. Recognize that fossils found in rocks are the remains of animals and plants that lived on Earth a long time ago.

Earth in the Solar System

1. Describe the solar system as a group of planets (including Earth) each revolving around the sun; recognize that the moon revolves around Earth; draw or describe the phases of the moon; and identify the sun as the source of heat and light for the solar system.
2. Relate daily patterns observed on Earth to Earth's rotation on its axis and its relationship to the sun (e.g., day and night, appearance of shadows).

Science Content Domains – Eighth Grade

Four major content domains – biology, chemistry, physics, and Earth science – define the science content covered in the eighth-grade assessment. It is important to note, however, that in an international assessment such as TIMSS the organization of science topics into these domains does not correspond to the structure of science instruction in all countries. In many countries, for example, science is taught as general science or integrated science whereas in others science is taught as separate subjects such as biology, physics, and chemistry. Additionally, some of the topics included in the TIMSS 2007 science framework may in some countries be taught in other courses, such as health education, social studies, or geography.

The content domains are shown in Exhibit 8 together with the target percentage devoted to each domain.

Exhibit 8: Target Percentages of the TIMSS 2007 Science Assessment Devoted to Content Domains at Eighth Grade

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

Each content domain has several main topic areas; each of which is presented as a list of objectives covered in the science curriculum in the majority of participating countries. The sections below describe each of the science content domains, give an overview of the topic areas to be covered in each domain, and provide a set of assessment objectives for each topic area. These objectives are written in terms of behaviors to be elicited by items that exemplify the understandings and abilities expected of students at eighth grade.

Biology

Biology includes students' understandings of the structure, life processes, diversity, and interdependence of living organisms.

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

Eighth-grade students are expected to be able to state the defining characteristics of major taxonomic groups and classify organisms according to these characteristics. They should also be able to locate major organs and relate the structure and function of organs and organ systems to basic biological processes.

Students should have a beginning understanding of cells and their function, as evidenced by their ability to describe cellular make up and to identify cell structures and relate them to their function. They also should be able to explain how certain biological processes such as photosynthesis and respiration are necessary to sustain life.

Students are expected to be able to distinguish between growth and development in different organisms. They also should be able to compare sexual and asexual reproduction in terms of biological processes at the cellular level, including ideas about heredity that involve the passing of genetic material from parent(s) to offspring.

Some understanding of diversity, adaptation, and natural selection among organisms is expected of eighth-grade students. They should have an appreciation of modern species in terms of similarity of characteristics and reproduction capabilities in a population of related organisms. They also should be able to relate diversity of characteristics to the survival or extinction of species in changing environments. Students are expected to start considering evidence for the history and

changes in Earth's life forms over time by the comparison of living species and fossil records.

The study of ecosystems is essential to understanding the interdependence of living organisms and their relationship to the physical environment. At the eighth grade, students should show introductory level understanding of the interdependence between populations of organisms that maintains balance in an ecosystem. They are expected to represent the flow of energy in an ecosystem, recognize the role of organisms in the cycling of materials, and predict the effects of changes in ecosystems. The effect of human activity on ecosystems is an important aspect of understanding the interdependence of living organisms and the environment.

Eighth-grade students are expected to demonstrate knowledge of human health, nutrition, and disease. They should know some causes of disease, communicate knowledge about the mechanisms of infection and transmission, and know the importance of the immune system. They also should be able to describe the role of specific nutrients in the functioning of the human body.

Biology: Characteristics, Classification, and Life Processes of Organisms

1. State the defining characteristics that differentiate among the major taxonomic groups and organisms within these groups, and classify organisms on the basis of a variety of physical and behavioral characteristics.
2. Locate major organs in the human body, identify the components of organ systems, and compare and contrast organs and organ systems in humans and other organisms.
3. Relate the structure and function of organs and organ systems to the basic biological processes required to sustain life (sensory, digestive, skeletal and muscular, circulatory, nervous, respiratory, excretory, reproductive).
4. Explain how biological actions in response to specific external and internal changes work to maintain stable bodily conditions (e.g., sweating in heat, shivering in cold, increased heart rate during exercise).

Biology: Cells and Their Functions

1. Describe the cellular make-up of all living organisms (both single-celled and multi-cellular), explain that cells carry out life functions and undergo cell division during growth and repair in organisms, and that tissues, organs, and organ systems are formed from groups of cells with specialized structures and functions.
2. Identify cell structures and some functions of cell organelles (cell wall, cell membrane, nucleus, cytoplasm, chloroplast, mitochondria, vacuoles); compare plant and animal cells.
3. Describe the process of photosynthesis that takes place in plant cells (the need for light, carbon dioxide, water, and chlorophyll; production of food; and release of oxygen).
4. Describe the process of respiration that takes place in plant and animal cells (the need for oxygen, breaking down of food to produce energy, and release of carbon dioxide).

Biology: Life Cycles, Reproduction, and Heredity

1. Compare and contrast how different organisms grow and develop (e.g., humans, plants, birds, insects).
2. Explain that reproduction (asexual or sexual) occurs in all living organisms and is important for the survival of species; compare and contrast biological processes in asexual and sexual reproduction in general terms (e.g., cell division producing identical offspring versus egg and sperm combination producing offspring that are similar but not identical to either parent); state advantages and disadvantages of each type of reproduction.
3. Relate the inheritance of traits to the passing on of genetic material contained in the cells of the parent(s) to their offspring; distinguish inherited characteristics from physical or behavioral features that are acquired or learned.

Biology: Diversity, Adaptation, and Natural Selection

1. Relate the survival or extinction of different species to variation in physical/behavioral characteristics in a population and reproductive success in changing environments.
2. Recognize the relative length of time major groups of organisms have existed on Earth (e.g., humans, reptiles, fish, plants); describe how similarities and differences among living species and fossils provide evidence of the changes that occur in living things over time.

Biology: Ecosystems

1. Describe the flow of energy in an ecosystem (the role of photosynthesis and respiration and the storage of food or energy products in organisms); identify different organisms as producers, consumers, and decomposers; draw or interpret food pyramids or food web diagrams.
2. Describe the role of organisms in the cycling of materials (e.g., oxygen, carbon dioxide, water) through Earth's surface and the decomposition of organisms and recycling of elements back into the environment.
3. Explain the interdependence of populations of organisms in an ecosystem in terms of the effects of competition and predation; identify factors that can limit population size (e.g., disease, predators, food resources, drought); predict effects of changes in an ecosystem (e.g., climate, water supply, food supply, population changes, migration) on the available resources and the balance among populations.
4. Recognize that the world's human population is growing and identify reasons why (e.g., advances in medicine, sanitation); discuss the effects of population growth on the environment.
5. Describe the impact of natural hazards (e.g., earthquakes, landslides, wildfires, volcanic eruptions, floods, storms) on humans, wild life, and the environment.

Biology: Human Health

1. Describe causes of common infectious diseases (e.g., influenza, measles, strep throat, AIDS), methods of infection or transmission, prevention, and the importance of the body's natural resistance (immunity) and healing capabilities.
2. Explain the importance of diet, hygiene, exercise, and lifestyle in maintaining health and preventing illness (e.g., heart disease, diabetes, skin cancer, lung cancer); identify the dietary sources and role of nutrients in a healthy diet (vitamins, minerals, proteins, carbohydrates, fats).

Chemistry

In the area of chemistry, students will be assessed on their understanding of concepts related to the following topic areas:

- Classification and composition of matter
- Properties of matter
- Chemical change

At the eighth grade, students should be able to classify substances on the basis of characteristic physical properties and recognize that substances can be grouped according to similar chemical and physical properties. They should differentiate between elements, compounds, and mixtures in terms of their composition. They also are expected to have a beginning understanding of the particulate structure of matter in terms of atoms and molecules.

Students should have a clear understanding of the properties of matter. They should describe methods of separating mixtures based on their physical properties; define solutions; and recognize the factors that affect the rate at which materials dissolve. Students also are expected to demonstrate knowledge of some properties and uses of metals and water, and be able to compare properties of acids and bases.

In the area of chemical change, students are expected to recognize the differences between physical and chemical changes and

demonstrate basic knowledge of conservation of matter during these changes. Students also are expected to recognize the need for oxygen in rusting and burning and the relative tendency of familiar substances to undergo these types of reactions. In addition, they should be able to identify common reactions that absorb or give off heat.

Chemistry: Classification and Composition of Matter

1. Classify or compare substances on the basis of characteristic physical properties that can be demonstrated or measured (e.g., density, thermal or electrical conductivity, solubility, melting or boiling point, magnetic properties).
2. Recognize that substances may be grouped according to similar chemical and physical properties; describe properties of metals that distinguish them from nonmetals.
3. Differentiate between pure substances (elements and compounds) and mixtures (homogeneous and heterogeneous) on the basis of their formation and composition, and provide or identify examples of each (solid, liquid, gas).
4. Describe the structure of matter in terms of particles, including molecules as combinations of atoms (e.g., H_2O, O_2, CO_2) and atoms as being composed of subatomic particles (electrons surrounding a nucleus containing protons and neutrons).

Chemistry: Properties of Matter

1. Select or describe physical methods for separating mixtures into their components (e.g., filtration, distillation, sedimentation, magnetic separation, flotation, dissolution).
2. Define solutions in terms of substance(s) (solid, liquid, or gas solutes) dissolved in a solvent; apply knowledge of the relationship between concentration or dilution and the amounts of solute or solvent; and of the effect of factors such as temperature, stirring, and particle size on the rate at which materials dissolve.

3. Relate the behavior and uses of water to its physical properties (e.g., melting point and boiling point, ability to dissolve many substances, thermal properties, expansion upon freezing).
4. Compare the properties of common acids and bases (acids have a sour taste and react with metals; bases usually have a bitter taste and slippery feel; strong acids and bases are corrosive; both acids and bases dissolve in water and react with indicators to produce different color changes; acids and bases neutralize each other).

Chemistry: Chemical Change

1. Differentiate chemical from physical changes in terms of the transformation (reaction) of one or more pure substances (reactants) into different pure substances (products); provide evidence that a chemical change has taken place based on common examples (e.g., temperature change, gas production, color change, light emission).
2. Recognize that mass is conserved during chemical change.
3. Recognize the need for oxygen in common oxidation reactions (combustion, rusting); compare the relative tendency of familiar substances to undergo these reactions (e.g., combustion of gasoline versus water, corrosion of steel versus aluminum).
4. Recognize that some chemical reactions give off heat while others absorb it; classify familiar chemical transformations as either releasing or absorbing heat (e.g., burning, neutralization, cooking).

Physics

In physics, students' understandings of concepts related to energy and physical processes will be assessed in the following topic areas:

- Physical states and changes in matter
- Energy transformations, heat, and temperature
- Light
- Sound
- Electricity and magnetism
- Forces and motion

Eighth-grade students should be able to describe processes involved in changes of state and begin to relate the states of matter to the distance and movement among particles. They also should be able to demonstrate understanding that mass is conserved during physical changes.

Concepts related to energy transformations, heat and temperature also are assessed at the eighth-grade level. Students are expected to be able to identify different forms of energy, describe simple energy transformations, and apply the principle of conservation of total energy in practical situations. Students also are expected to recognize heat as the transfer of energy, and to relate temperature to the movement or speed of particles.

Students at the eighth grade are expected to know some basic properties of light and its interaction with matter; to use simple geometrical optics to solve practical problems; and to relate the appearance and color of objects to light properties. Students also are expected to recognize the characteristics of sound and some of its properties.

In the area of electricity and magnetism, assessment of students' understandings of electricity includes current flow in complete circuits, simple circuit diagrams, and the relationship between current and voltage in circuits. They also are expected to be able to describe properties and forces of permanent magnets, as well as the essential features and uses of electromagnets.

Students are expected to have a quantitative knowledge of mechanics. They should be able to represent motion, compute speed, interpret distance versus time graphs, and predict changes in the motion of an object based on the forces acting upon it. They also should demonstrate commonsense understanding of density and pressure as they relate to familiar physical phenomena, although more formalized knowledge is not expected.

Physics: Physical States and Changes in Matter

1. Use knowledge about the movement of and distance between particles to explain differences in the physical properties of solids, liquids, and gases (volume, shape, density, compressibility).
2. Describe the processes of melting, freezing, boiling, evaporation, and condensation as changes of state resulting from the supplying or removing of heat; relate the rate or extent of these processes to common physical factors (surface area, dissolved substances, temperature, altitude or pressure).
3. Recognize that temperature remains constant during changes of state (melting, boiling, freezing).
4. Recognize that mass is conserved during physical changes (e.g., change of state, dissolving solids, thermal expansion).

Physics: Energy Transformations, Heat, and Temperature

1. Identify different forms of energy (e.g., mechanical, light, sound, electrical, thermal, chemical); describe simple energy transformations (e.g., combustion in an engine to move a car, electrical energy to power a lamp, light energy to chemical energy in photosynthesis, hydroelectric power, changes between potential and kinetic energy); and apply knowledge of the concept of conservation of total energy.
2. Relate heat to the transfer of energy from an object at a high temperature to one at a lower temperature; compare the relative thermal conductivity of different materials; and compare and contrast methods of heat transfer (conduction, convection, and radiation).
3. Relate temperature changes to changes in volume and/or pressure and to changes in the movement or speed of particles.

Physics: Light

1. Describe or identify some basic properties or behaviors of light (transmission from a source through different media; speed of light compared to sound; reflection, refraction {bending}, absorption, and transmission by different materials; splitting of white light into its component colors by prisms and other dispersive media).
2. Relate the appearance or color of objects to the properties of reflected or absorbed light.
3. Solve practical problems involving the reflection of light from plane mirrors and the formation of shadows; interpret ray diagrams to identify the path of light and locate reflected or projected images using lenses.

Physics: Sound

1. Recognize the characteristics of sound (loudness, pitch, amplitude, frequency).
2. Describe or identify some basic properties of sound (transmission from a source through a medium, reflection and absorption by surfaces, and relative speed through different media).

Physics: Electricity and Magnetism

1. Describe the flow of current in an electrical circuit; draw or identify diagrams representing complete circuits (series and parallel); classify materials as electrical conductors or insulators; and recognize that there is a relationship between current and voltage in a circuit.
2. Describe the properties of permanent magnets and the effects of magnetic force; identify essential features and practical uses of electromagnets (e.g., doorbell).

Physics: Forces and Motion

1. Represent the motion of an object in terms of its position, direction, and speed in a given reference frame; compute speed from time and distance using standard units; and use information in distance versus time graphs.
2. Describe general types of forces (e.g., weight as a force due to gravity, contact force, buoyant force, friction); predict changes in motion (if any) of an object based on the forces acting on it.
3. Demonstrate basic knowledge of work and the function of simple machines (e.g., levers) using common examples.
4. Explain observable physical phenomena in terms of density differences (e.g., floating or sinking objects, rising balloons).
5. Describe effects related to pressure (e.g., atmospheric pressure as a function of altitude, ocean pressure as a function of depth, evidence of gas pressure in balloons, spreading force over a large or small area, fluid levels).

Earth Science

Earth science is concerned with the study of Earth and its place in the solar system and the universe. 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, physics, and chemistry. 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. While there is no single picture of what constitutes an Earth science curriculum that applies to all countries, the TIMSS 2007 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
- 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. They are expected to demonstrate knowledge of the structure and physical characteristics of Earth's crust, mantle, and core, and to describe the distribution of water on Earth, including its physical state, composition, and movement. Students are expected to be familiar with the relative abundance of the main components of air, and with changes in atmospheric conditions in relation to altitude.

In the area of Earth's processes, cycles, and history, students should provide descriptions based on the concept of cycles and patterns. In particular, they should be able to describe in words or diagrams the rock and water cycle. Students are expected to interpret and use data or maps relating global and local factors to weather patterns, and to differentiate between daily weather changes and general climate in various regions of the world. Students are expected to have a sense of the magnitude of time scales, and to describe some physical processes and geological events that have taken place on Earth over billions of years.

Students should be able to demonstrate knowledge of Earth's resources and their use and conservation by providing examples of renewable and non renewable resources, by relating the effects of human use of land resources to methods used in agriculture, and by discussing the factors related to the supply and demand of fresh water.

Eighth-grade students are expected to have some knowledge of the solar system in terms of the relative distances, sizes, and motions of the sun, the planets, and their moons, and of how phenomena on Earth relate to the motion of bodies in the solar system. Students also are expected to compare the physical features of Earth, the moon, and the other planets with respect to their ability to support life.

Earth Science: Earth's Structure and Physical Features

1. Describe the structure and physical characteristics of Earth's crust, mantle, and core; use and interpret topographic maps; describe the formation, characteristics, and uses of soils, minerals, and basic rock types.
2. Compare the physical state, movement, composition and relative distribution of water on Earth (e.g., oceans, rivers, ground water, glaciers, ice caps, clouds).
3. Recognize that Earth's atmosphere is a mixture of gases, and identify the relative abundance of its main components; relate changes in atmospheric conditions (temperature, pressure, composition) to altitude.

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

1. Describe the general processes involved in the rock cycle (weathering/erosion, deposition, heating/compression, melting/freezing, lava flow) resulting in the continuous formation of igneous, metamorphic, and sedimentary rock.
2. Diagram or describe the steps in Earth's water cycle (evaporation, condensation, and precipitation), referencing the sun as the source of energy and the role of cloud movement and water flow in the circulation and renewal of fresh water on Earth's surface.
3. Interpret weather data or maps, and relate changing weather patterns to global and local factors in terms of temperature, pressure, precipitation, wind speed and direction, cloud types and formation, and storm fronts.
4. Compare seasonal climates of major regions on Earth, considering effects of latitude, altitude and geography (e.g., mountains and oceans); identify or describe long- and short-term climatic changes (e.g., ice ages, global warming trends, volcanic eruptions, changes in ocean currents).
5. Identify or describe physical processes and major geological events that have occurred over millions of years (e.g., weathering, erosion, deposition, volcanic activity,

earthquakes, mountain building, plate movement, continental drift); explain the formation of fossils and fossil fuels.

6. Relate some environmental concerns to their possible causes and effects (e.g., pollution, global warming, acid rain, depletion of the ozone layer, deforestation, desertification); present ways in which science and technology can be used to address these concerns.

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

1. Provide common examples of renewable and nonrenewable resources; discuss advantages and disadvantages of different energy sources; and describe methods of conservation and waste management (e.g., recycling).
2. Relate effects of human use of land or soil resources (e.g., farming, tree harvesting, mining) to methods used in agriculture and land management (e.g., crop rotation, fertilization, pest control, reforesting).
3. Discuss factors related to the supply and demand of fresh water and use of water resources (e.g., purification, desalination, irrigation, use of dams, conservation).

Earth Science: Earth in the Solar System and the Universe

1. Explain phenomena on Earth (day and night, tides, year, phases of the moon, eclipses, seasons in the northern and southern hemisphere, appearance of sun, moon, planets, and constellations) in terms of the relative movements, distances, and sizes of Earth, the moon, and other bodies in and outside the solar system.
2. Recognize the role of gravity in the solar system (e.g., tides, keeping the planets and moons in orbit, pulling us to Earth's surface).
3. Compare and contrast the physical features of Earth with the moon and other planets (e.g., atmosphere, temperature, water, distance from the sun, period of revolution and rotation, ability to support life).

Science Cognitive Domains – Fourth and Eighth Grades

To respond correctly to TIMSS test items, students need to be familiar with the science content being assessed, but they also need to draw on a range of cognitive skills. Describing these skills plays a crucial role in the development of an assessment like TIMSS 2007, since they are vital in ensuring that the survey covers the appropriate range of cognitive skills across the content domains already outlined.

This section outlines the skills and abilities associated with the cognitive dimension.

The cognitive dimension is divided into three domains based on what students have to know and do when confronting the various items developed for the TIMSS 2007 assessment. The first domain, *Knowing*, covers facts, procedures, and concepts students need to know, while the second domain, *Applying*, focuses on the ability of the student to apply knowledge and conceptual understanding in a problem situation. The third domain, *Reasoning*, goes beyond the solution of routine problems to encompass unfamiliar situations, complex contexts, and multi-step problems.

These three cognitive domains are used at both grades, however the percentages vary between fourth and eighth grade in accordance with the increased cognitive ability, maturity, instruction, experience, and breadth and depth of understanding of students at the higher grade level (see Exhibit 9). Thus 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. For fourth and eighth grades, each content domain will include 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.

Exhibit 9: Target Percentages of the TIMSS 2007 Science Assessment Devoted to Cognitive Domains at Fourth and Eighth Grades

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

While some hierarchy is imposed in the division of behaviors into the three cognitive domains, a range of difficulty levels is expected for items developed for each of the cognitive domains. The following sections further describe the student skills and abilities defining the cognitive domains. The general descriptions are followed by lists of specific behaviors to be elicited by items that are aligned with each domain.

Knowing

Knowing refers to students' knowledge base of science facts, information, concepts, tools, and procedures. Accurate and broad-based factual knowledge enables students to engage successfully in the more complex cognitive activities essential to the scientific enterprise. Students are expected to recall or recognize accurate science statements; possess knowledge of vocabulary, facts, information, symbols, units, and procedures; and select appropriate apparatus, equipment, measurement devices, and experimental operations to use in conducting investigations. This cognitive domain also includes the selection of illustrative examples in support of statements of facts or concepts.

1.	**Recall/ Recognize**	Make or identify accurate statements about science facts, relationships, processes, and concepts; identify the characteristics or properties of specific organisms, materials, and processes.
2.	**Define**	Provide or identify definitions of scientific terms; recognize and use scientific vocabulary, symbols, abbreviations, units, and scales in relevant contexts.

3.	**Describe**	Describe organisms, physical materials, and science processes that demonstrate knowledge of properties, structure, function, and relationships.
4.	**Illustrate with Examples**	Support or clarify statements of facts or concepts with appropriate examples; identify or provide specific examples to illustrate knowledge of general concepts.
5.	**Use Tools and Procedures**	Demonstrate knowledge of the use of science apparatus, equipment, tools, procedures, measurement devices, and scales.

Applying

The questions in this cognitive domain are designed to involve the direct application of knowledge and understanding in straight forward situations. To measure *applying*, TIMSS 2007 will include items that require students to compare, contrast, and classify, to interpret scientific information in light of a science concept or principle, and to use and apply their understanding of science concepts and principles to find a solution or develop an explanation. Items aligned with this cognitive domain will involve the direct application or demonstration of relationships, equations, and formulas in contexts likely to be familiar in the teaching and learning of science concepts. Both quantitative problems requiring a numerical solution and qualitative problems requiring a written descriptive response are included. In providing explanations, students should be able to use diagrams or models to illustrate structures and relationships and demonstrate knowledge of scientific concepts.

1.	**Compare/ Contrast/ Classify**	Identify or describe similarities and differences between groups of organisms, materials, or processes; distinguish, classify, or order individual objects, materials, organisms, and processes based on given characteristics and properties.
2.	**Use Models**	Use a diagram or model to demonstrate understanding of a science concept, structure, relationship, process, or biological or physical system or cycle (e.g., food web, electrical circuit, water cycle, solar system, atomic structure).
3.	**Relate**	Relate knowledge of an underlying biological or physical concept to an observed or inferred property, behavior, or use of objects, organisms, or materials.
4.	**Interpret Information**	Interpret relevant textual, tabular, or graphical information in light of a science concept or principle.
5.	**Find Solutions**	Identify or use a science relationship, equation, or formula to find a qualitative or quantitative solution involving the direct application/demonstration of a concept.
6.	**Explain**	Provide or identify an explanation for an observation or natural phenomenon, demonstrating understanding of the underlying science concept, principle, law, or theory.

Reasoning

Reasoning is involved in the more complex tasks related to science. A major purpose of science education is to prepare students to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, make decisions, and extend their knowledge to new situations. In addition to the more direct applications of science concepts exemplified in the applying domain, some problem-solving situations involve unfamiliar or more complicated contexts that require students to reason from scientific principles to provide an answer. Solutions may involve breaking down a problem into component parts, each involving the application of a science concept or relationship. Students may be required to analyze a problem to determine what underlying principles are involved; devise and explain strategies for problem solving; select and apply appropriate equations, formulas, relationships, or analytical techniques; and evaluate their solutions. Correct solutions to such problems may stem from a variety of approaches or strategies, and developing the ability to consider alternative strategies is an important educational goal in the teaching and learning of science.

Students may be required to draw conclusions from scientific data and facts, providing evidence of both inductive and deductive reasoning and of an understanding of the investigation of cause and effect. They are expected to evaluate and make decisions, weigh advantages and disadvantages of alternative materials and processes, consider the impact of different scientific endeavors, and evaluate solutions to problems. By the eighth grade, in particular, students should consider and evaluate alternative explanations, extend conclusions to new situations, and justify explanations based on evidence and scientific understanding. Considerable scientific reasoning also is involved in developing hypotheses and designing scientific investigations to test them, and in analyzing and interpreting data. Abilities in this area are introduced at a very basic level in primary school and then further developed throughout students' science education in middle and secondary school.

Some items in this cognitive domain may focus on unified concepts and major conceptual themes, requiring students to bring together knowledge and understanding from different areas and apply it to new situations. As such, they may involve the integration of mathematics and science and/or the integration and synthesis of concepts across the domains of science.

1.	**Analyze/ Solve Problems**	Analyze problems to determine the relevant relationships, concepts, and problem-solving steps; develop and explain problem-solving strategies.
2.	**Integrate/ Synthesize**	Provide solutions to problems that require consideration of a number of different factors or related concepts; make associations or connections between concepts in different areas of science; demonstrate understanding of unified concepts and themes across the domains of science; integrate mathematical concepts or procedures in the solutions to science problems.
3.	**Hypothesize/ Predict**	Combine knowledge of science concepts with information from experience or observation to formulate questions that can be answered by investigation; formulate hypotheses as testable assumptions using knowledge from observation and/or analysis of scientific information and conceptual understanding; make predictions about the effects of changes in biological or physical conditions in light of evidence and scientific understanding.

4.	**Design/Plan**	Design or plan investigations appropriate for answering scientific questions or testing hypotheses; describe or recognize the characteristics of well-designed investigations in terms of variables to be measured and controlled and cause-and-effect relationships; make decisions about measurements or procedures to use in conducting investigations.
5.	**Draw Conclusions**	Detect patterns in data, describe or summarize data trends, and interpolate or extrapolate from data or given information; make valid inferences on the basis of evidence and/or understanding of science concepts; draw appropriate conclusions that address questions or hypotheses, and demonstrate understanding of cause and effect.
6.	**Generalize**	Make general conclusions that go beyond the experimental or given conditions, and apply conclusions to new situations; determine general formulas for expressing physical relationships.
7.	**Evaluate**	Weigh advantages and disadvantages to make decisions about alternative processes, materials, and sources; consider scientific and social factors to evaluate the impact of science and technology on biological and physical systems; evaluate alternative explanations and problem-solving strategies and solutions; evaluate results of investigations with respect to sufficiency of data to support conclusions.

8.	**Justify**	Use evidence and scientific understanding to justify explanations and problem solutions; construct arguments to support the reasonableness of solutions to problems, conclusions from investigations, or scientific explanations.

Scientific Inquiry

In the contemporary science curricula of many countries, considerable emphasis is placed on engaging students in scientific inquiry. The goal of scientific inquiry is to provide explanations of scientific phenomena that help us understand the underlying principles governing the natural world. At the fourth- and eighth-grade level, students are not expected to be formulating and testing fundamental theories, but they should be able to pose scientific questions or hypotheses of limited scope that can be investigated. At these grade levels, scientific inquiry involves students in the process of questioning, planning, and conducting investigations to gather evidence, and formulating explanations based on observations and in light of scientific understanding. The understandings and abilities required to engage in this type of scientific investigation are important in developing citizens who are literate in the methods, processes, and products of science. They are also precursors of the more advanced types of inquiry directed at furthering scientific knowledge that are important in preparing future scientists. Given that the scientific inquiry process is an integral part of learning and doing science, it is important to assess students' understandings and abilities required to engage in this process successfully.

Scientific inquiry is treated as an overarching assessment strand in the TIMSS 2007 framework. It overlaps all of the fields of science and has both content- and skills-based components. Assessment of scientific inquiry includes items and tasks requiring students to demonstrate knowledge of the tools, methods, and procedures necessary to do science, to apply this knowledge to engage in scientific investigations, and to use scientific understanding to propose explanations

based on evidence. These processes of scientific inquiry promote a broader understanding of science concepts as well as reasoning and problem-solving skills.

It is expected that students at both grade levels will possess some general knowledge of the nature of science and scientific inquiry, including the fact that scientific knowledge is subject to change, the importance of using different types of scientific investigations in verifying scientific knowledge, the use of basic "scientific methods", communication of results, and the interaction of science, mathematics, and technology. In addition to this general knowledge, students are expected to demonstrate the skills and abilities involved in five major aspects of the scientific inquiry process:

- Formulating questions and hypotheses
- Designing investigations
- Representing data
- Analyzing and interpreting data
- Drawing conclusions and developing explanations

These aspects of scientific inquiry are appropriate for both fourth- and eighth-grade students, but the understandings and abilities to be demonstrated increase in complexity across grades, reflecting the cognitive development of students.

The learning of science in the fourth grade is focused on observing and describing, and students at this level are expected to be able to formulate questions that can be answered based on observations or information obtained about the natural world. To obtain evidence to answer these questions, they should demonstrate a grasp of what constitutes a "fair test", and be able to describe and conduct an investigation based on making systematic observations or measurements using simple tools, equipment, and procedures. They also are expected to represent their findings using simple charts and diagrams, apply routine mathematical computations of measured values, identify simple relationships, and briefly describe the results of their investigations. Conclusions drawn

from investigations at the fourth grade are expected to be written as an answer to a specific question.

By the eighth grade, students should demonstrate a more quantitative and formalized approach to scientific investigation that involves more evaluation and decision-making. They are expected to be able to formulate a hypothesis or prediction based on observation or scientific knowledge that can be tested by investigation. They are expected to demonstrate an understanding of cause and effect and the importance of specifying variables to be controlled and varied in well-designed investigations. They may also be required to make more decisions about the measurements to be made and the equipment and procedures to use. In addition, students at this level are expected to use appropriate terminology, units, precision, format, and scales. They should also demonstrate more advanced data analysis skills in selecting and applying appropriate mathematical techniques and describing patterns in data. Eighth-grade students may be expected to evaluate the results of their investigation with respect to the sufficiency of their data for supporting conclusions that address the question or hypothesis under investigation.

The assessment of both fourth- and eighth-grade students' ability to provide explanations based on evidence from scientific investigations provides another measure of their understanding and application of related science concepts. By the eighth grade, it is expected that students will be able to formulate explanations in terms of cause-and-effect relationships between variables and in light of scientific understanding. At this level, students may also begin to consider alternative explanations and apply or extend their conclusions to new situations.