Exhibit 2.2.3: Summary of TIMSS 2023 International Benchmarks of Science Achievement

Advanced International Benchmark

625 *Students can show, apply, and reason with knowledge of concepts related to biology, chemistry, physics, and earth science in various contexts, and they can engage in more complex scientific practices.* Students show knowledge of cellular respiration, photosynthesis, and natural disasters. They can apply knowledge about the human immune system and reason about ancestry. Students show and can apply knowledge of atoms, molecules, acids and bases, and chemical reactions, and can reason about separating mixtures. Students show knowledge about unbalanced forces and can apply knowledge about friction and the properties of sound. They can reason about shadows. They show knowledge about the composition of Earth's oceans and atmosphere, Earth's processes and history, and Earth's resources and their uses. Students can describe one limitation of a model and design a fair test with multiple variables.

High International Benchmark

550 *Students show and apply knowledge of concepts from biology, chemistry, physics, and earth science, and they engage in multiple scientific practices.* They show and apply knowledge of plant and animal cells, know simple facts about inheritance, and reason about simple population dynamics in an ecosystem. Students can apply knowledge of the human body and of the effects of human behavior on the environment. Students show some knowledge of subatomic particles and of chemical notation and can reason about a chemical reaction. They can apply knowledge of properties of matter, electromagnets, light absorption and reflection, and the direction of common forces. They demonstrate knowledge about the states of matter, the transfer of thermal energy, and energy transformation. Students show knowledge about light from the Sun and about Earth's resources. They can apply knowledge about the relationship between climate and both weather and weathering. Students can interpret patterns in data, reason with data and graphical information, explore relationships between variables, and predict outcomes.

Intermediate International Benchmark

475 *Students can apply understanding of some concepts from biology, chemistry, physics, and earth science, and they engage in some scientific practices.* They can apply knowledge about health, energy flow in ecosystems, interactions among living things and with their environment, and reproduction and inheritance. Students can apply knowledge of some chemistry concepts, such as thermal and electrical conductivity, concentration of a solution, and chemical reactions. They show basic knowledge of states of matter, motion, and forces, and they apply knowledge of properties of materials and of light. Students show some knowledge of the physical structure of the Earth, the Earth-Moon-Sun system, and the water cycle. They can reason about Earth's climate and demonstrate knowledge of ways to manage Earth's natural resources. Students create a simple experimental design and a basic mathematical model. They interpret tables, graphs, and pictures, and they draw conclusions.

Low International Benchmark

400 *Students show and apply knowledge of some science facts.* They show knowledge about cells, tissues, and organs and about some characteristics of animals. They apply some knowledge of ecosystems using models. Students distinguish between physical and chemical changes, and they show some knowledge related to dissolving. Students show basic knowledge about the physical properties of matter and about the form of energy a common device uses. Students know that ocean water contains salt and the Sun provides light and heat. Students can describe an observation and interpret a model.

Exhibit 2.2.5: Description of the TIMSS 2023 Low International Benchmark (400) of Science Achievement

Low International Benchmark

400

Summary

Students show and apply knowledge of some science facts. They show knowledge about cells, tissues, and organs and about some characteristics of animals. They apply some knowledge of ecosystems using models. Students distinguish between physical and chemical changes, and they show some knowledge related to dissolving. Students show basic knowledge about the physical properties of matter and about the form of energy a common device uses. Students know that ocean water contains salt and the Sun provides light and heat. Students can describe an observation and interpret a model.

Students can identify cells as the basic unit of all living things. They know the functions of major tissues and organs. Students recognize common animals that lay eggs, and students have basic knowledge about features or behaviors that help mammals survive in cold weather.

Students can complete a food chain, interpret a food web, and place organisms into an energy pyramid. They can identify organisms that compete for food and predator-prey relationships in the food web. Students reason that the population of predators depends on the prey population and vice versa.

Students can distinguish between physical and chemical changes. They show knowledge of multiple ways to increase the rate at which solutes dissolve. Students can determine mass using a balance.

Students can apply knowledge about which materials are attracted to a magnet. They recognize the phase change that occurs when thermal energy is added to liquid water and the relative distance between particles in a gas. They recognize the type of energy a common device uses and the property that explains floating and sinking.

Students show knowledge that salt must be removed from clean ocean water to make it safe to drink and that the Sun provides light and heat.

Students can describe an observation and interpret a model.

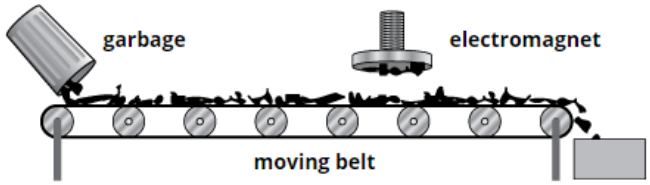
Exhibit 2.2.5a: TIMSS 2023 Low International Benchmark (400) of Science Achievement – Example Item 1

Content Domain: Physics

Cognitive Domain: Applying

Description: Recognizes whether an electromagnet would attract objects made of various materials

The diagram shows garbage being dumped onto a moving belt. Some of the garbage is being removed by an electromagnet and the rest falls into the box.



What happens to each of the following materials?

(Click one circle in each row.)

	Removed by the electromagnet	Fall into the box
steel cans	A	B
plastic cups	A	B
aluminum cans	A	B
newspapers	A	B
iron nails	A	B

Exhibit 2.2.6: Description of the TIMSS 2023 Intermediate International Benchmark (475) of Science Achievement

Intermediate International Benchmark

475

Summary

Students can apply understanding of some concepts from biology, chemistry, physics, and earth science, and they engage in some scientific practices. They can apply knowledge about health, energy flow in ecosystems, interactions among living things and with their environment, and reproduction and inheritance. Students can apply knowledge of some chemistry concepts, such as thermal and electrical conductivity, concentration of a solution, and chemical reactions. They show basic knowledge of states of matter, motion, and forces, and they apply knowledge of properties of materials and of light. Students show some knowledge of the physical structure of the Earth, the Earth-Moon-Sun system, and the water cycle. They can reason about Earth's climate and demonstrate knowledge of ways to manage Earth's natural resources. Students create a simple experimental design and a basic mathematical model. They interpret tables, graphs, and pictures, and they draw conclusions.

Students can identify producers and primary consumers in a food web and apply basic knowledge of energy flow through the energy pyramid. They can apply knowledge about the interactions among living things and with their environment and demonstrate knowledge of the characteristics of plants, animals, and their environmental adaptations. Students can distinguish between inherited animal characteristics from those acquired. They can identify the reproductive organ in flowering plants and the chloroplast as a distinguishing structure between plant and animal cells. Students can complete a simplified diagram of the oxygen-carbon dioxide cycle. They can apply knowledge about a healthy diet and identify some behaviors associated with health or developing common diseases.

Students can relate the use of a material to its thermal conductivity. They can reason about the concentration of a solution based on the amounts of solute and solvent. Students can recognize that a chemical reaction can produce gases and that the rate of reaction in a common context can be increased by increasing surface area.

Students apply knowledge of heat and electrical conduction to separate insulators from conductors. They can relate some knowledge of magnetic force to an everyday context, and they reason about the reflection of light. Students can recognize the state of water at different temperatures and name the changes in states of water. Students can show knowledge of balanced forces in floating and sinking and the direction of the force of gravity. Students can recognize constant speed as a steady change of distance over time.

Students can state the motion of Earth that results in day and night, relate a phase of the Moon to its relative position to the Earth, and know the primary component of Earth's crust. They can apply some knowledge of rainfall and temperature in different climates, show knowledge of the processes in the Earth's water cycle, and identify evidence (other than temperature data) of an increasing global temperature. Students can identify renewable energy sources and classify some human activities as reducing, reusing, or recycling.

Students can interpret tabular and graphical information, reason with pictorial information, create an experimental design, model a physical situation using a simple mathematical formula, and draw conclusions.

Exhibit 2.2.6a: TIMSS 2023 Intermediate International Benchmark (475) of Science Achievement – Example Item 1

Content Domain: Biology

Cognitive Domain: Reasoning

Description: Justifies an advantage of hollow bones for birds

The bones of birds are hollow.

What advantage do hollow bones give to birds?

Hollow bones make it easier for birds to fly

The answer shown illustrates one type of response that would receive full credit.
Other types of correct responses are possible as defined by the item's unique scoring guide.

Exhibit 2.2.6b: TIMSS 2023 Intermediate International Benchmark (475) of Science Achievement – Example Item 2

Content Domain: Biology

Cognitive Domain: Knowing

Description: Recognizes characteristics inherited by rabbits in a given context

Francisco is a farmer who raises rabbits. He breeds a female rabbit and a male rabbit. A litter of 10 young rabbits is produced.

Which of the following best describes the characteristics of the young rabbits?

A. About half of the young rabbits will look like the female rabbit, and about half of them will look like the male rabbit.

B. All of the young rabbits will look just like the female rabbit because young rabbits inherit their traits from their mother.

C. All of the young rabbits will look just like the male rabbit because male traits are dominant.

D. All of the young rabbits will look like the female rabbit in some ways and like the male rabbit in some ways.

Exhibit 2.2.7: Description of the TIMSS 2023 High International Benchmark (550) of Science Achievement

High International Benchmark

550

Summary

Students show and apply knowledge of concepts from biology, chemistry, physics, and earth science, and they engage in multiple scientific practices. They show and apply knowledge of plant and animal cells, know simple facts about inheritance, and reason about simple population dynamics in an ecosystem. Students can apply knowledge of the human body and of the effects of human behavior on the environment. Students show some knowledge of subatomic particles and of chemical notation and can reason about a chemical reaction. They can apply knowledge of properties of matter, electromagnets, light absorption and reflection, and the direction of common forces. They demonstrate knowledge about the states of matter, the transfer of thermal energy, and energy transformation. Students show knowledge about light from the Sun and about Earth's resources. They can apply knowledge about the relationship between climate and both weather and weathering. Students can interpret patterns in data, reason with data and graphical information, explore relationships between variables, and predict outcomes.

Students can identify the functions of different human cell types and recognize what happens to animal cells as they grow. They can apply knowledge of a distinguishing structure between plant and animal cells, and they know the part of a plant that passes genetic information to its offspring. Students can identify the defining characteristics that differentiate between animals from major taxonomic groups. Students can reason about how changes in an ecosystem affect the dynamics of prey and predator populations. They can apply knowledge of the body's immune system to contracting a common disease, and they reason about the human body's physiological responses. Students can locate major organs in systems of the human body. They can apply knowledge about positive or negative effects of human behavior on the environment.

Students can relate the use of a material to its thermal properties. They show some knowledge of the three types of subatomic particles and can interpret a chemical formula. They can interpret information in a table to determine the density of a metal and they provide one variable that should be held constant during an investigation of reactivity. They can reason about a chemical reaction between two reactants that were used up.

Students can apply knowledge about the properties of electromagnets, the absorption and reflection of different colors of light, the direction of common forces (weight, buoyant force, air resistance), and density. They can identify the states of matter of various materials at room temperature and they relate the rate of change of state to the size of the object. They can recognize the way temperature changes over time in an object that is warmer or cooler than its surroundings. They can recognize energy transformation involving kinetic and chemical energy.

Students can recognize how the Sun produces its own light and how that light makes planets visible from Earth. They can recognize an effect of forest clearing and that the release of a greenhouse gas can affect Earth's climate. They can identify advantages and disadvantages of different energy sources. They can relate climatic conditions to the weathering of rocks, and they can relate temperature data to the hemisphere and proximity to the ocean. Students can apply knowledge about rainfall and temperature in different climates.

Students can interpret patterns in data, reason with quantitative data and graphical information, explore relationships between variables, use a model, and predict outcomes.

Exhibit 2.2.7a: TIMSS 2023 High International Benchmark (550) of Science Achievement – Example Item 1

Content Domain: Chemistry

Cognitive Domain: Knowing

Description: Identifies the number of atoms of each element in nitric acid

Complete the table below to show the number of atoms of each element needed to form a molecule of nitric acid (HNO_3).

Element	Number of atoms
Hydrogen (H)	1
Nitrogen (N)	1
Oxygen (O)	3

Exhibit 2.2.7b: TIMSS 2023 High International Benchmark (550) of Science Achievement – Example Item 2

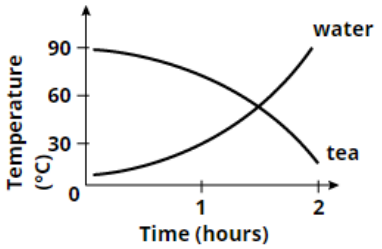
Content Domain: Physics

Cognitive Domain: Applying

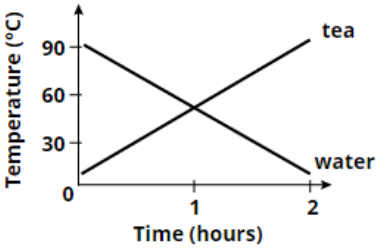
Description: Relates knowledge of heat transfer to recognize a graph that shows how two substances eventually reach temperature equilibrium

Lucy placed a glass of hot tea next to a glass of cold water on the table. Which of the graphs shows how the temperatures of the tea and the water changed over the next two hours? Assume the temperature in the room is 25°C.

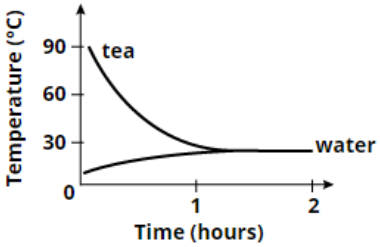
A



B



C



D

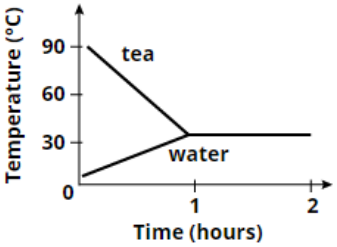


Exhibit 2.2.8: Description of the TIMSS 2023 Advanced International Benchmark (625) of Science Achievement

Advanced International Benchmark

625

Summary

Students can show, apply, and reason with knowledge of concepts related to biology, chemistry, physics, and earth science in various contexts, and they can engage in more complex scientific practices. Students show knowledge of cellular respiration, photosynthesis, and natural disasters. They can apply knowledge about the human immune system and reason about ancestry. Students show and can apply knowledge of atoms, molecules, acids and bases, and chemical reactions, and can reason about separating mixtures. Students show knowledge about unbalanced forces and can apply knowledge about friction and the properties of sound. They can reason about shadows. They show knowledge about the composition of Earth's oceans and atmosphere, Earth's processes and history, and Earth's resources and their uses. Students can describe one limitation of a model and design a fair test with multiple variables.

Students show some knowledge about the components and function of the human immune system and can apply knowledge about how vaccination affects it. They can apply basic knowledge of cellular respiration and photosynthesis, and they can reason using evidence of common ancestry. They can apply knowledge about how natural disasters affect human life.

Students show knowledge of the arrangement of subatomic particles, and they can use a model to describe molecules as combinations of atoms. They can apply knowledge of the number of protons in the nuclei to complete the periodic table and to predict the location of elements based on their properties. They can recognize that the composition of an object affects the amount of rust produced, and whether substances are an acid or a base based on their pH value or a color indicator. They show knowledge of categories of substances that react with acid. They can reason about physical methods that can be used to separate mixtures into their components. Students show knowledge of several factors that can affect a reaction rate, and they can recognize that new chemical bonds form after a chemical reaction.

Students show knowledge about unbalanced forces in floating and sinking and about forces and distances in a simple machine. They show knowledge about the comparison of the mass, force of gravity on, and motion of an object on the Earth and on the Moon. They can recognize acceleration as an increasing change of distance over time. They can apply knowledge about friction and the properties of sound in different contexts, of permanent magnets, of gases and liquids in a laboratory setting, and of molecules in solids. Students can reason about the formation of shadows.

Students can recognize that salt water is found only in the ocean and that nitrogen makes up most of the Earth's atmosphere. They can identify the relationship between altitude and temperature in the Earth's atmosphere. Students can identify the processes of changes to the Earth's surface and the formation of fossil fuels. They can explain how trees can prevent flooding and identify a negative effect of human activity on the environment.

Students can describe one limitation of a model and design a fair test with multiple variables.

Exhibit 2.2.8a: TIMSS 2023 Advanced International Benchmark (625) of Science Achievement – Example Item 1

Content Domain: Earth Science

Cognitive Domain: Knowing

Description: Recognizes the gas that makes up most of Earth's atmosphere

Which of the following gases makes up most of Earth's atmosphere?

A nitrogen

B oxygen

C water vapor

D carbon dioxide

Exhibit 2.2.8b: TIMSS 2023 Advanced International Benchmark (625) of Science Achievement – Example Item 2

Content Domain: Chemistry

Cognitive Domain: Applying

Description: Identifies and explains whether a described change is physical or chemical

An iron object is changing color and small bits of material are flaking off of the object's surface.

Is the process that is affecting the iron object a physical change or a chemical change?

(Click one box.)

- ☐ physical change
- ☑ chemical change

Explain your answer.

The iron changed color and new products are formed.

The answer shown illustrates one type of response that would receive full credit.
Other types of correct responses are possible as defined by the item's unique scoring guide.