TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

TIMSS

TIMSS 2019 Assessment Frameworks

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Editors

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Introduction

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Introduction

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TIMSS 2019: Monitoring Trends in Mathematics and Science Achievement

Entering into its third decade and seventh cycle of data collection, TIMSS (Trends in International Mathematics and Science Study) is a well established international assessment of mathematics and science at the fourth and eighth grades. TIMSS 2019 is the most recent in the TIMSS trend series, which began with the first assessments in 1995 and continued every four years—1999, 2003, 2007, 2011, 2015, and 2019. About 60 countries use TIMSS trend data for monitoring the effectiveness of their educational systems in a global context, and new countries join TIMSS in each cycle. About 70 countries are expected to participate in TIMSS 2019.

As a mathematics and science assessment, TIMSS is a valuable resource for monitoring educational effectiveness because science, technology, engineering, and mathematics, often known as STEM, are key curriculum areas. It is clear that even today many jobs require a basic understanding of mathematics and science, and this will become increasingly so in the future. Workers in STEM occupations are responsible for finding solutions to world problems such as hunger and disappearing habitats as well as sustaining growth and stability in the global economy. Mathematics and science also are basic to daily life. Science is the natural world, including our weather, land and water, and sources of food and fuel. Mathematics helps us manage a host of daily tasks and is essential in developing the technology we depend on, such as computers, smartphones, and television.

Because mathematics and science pervade every aspect of our lives, the International Association for the Evaluation of Educational Achievement, more widely known as IEA, has been conducting international assessments of mathematics and science for nearly 60 years.

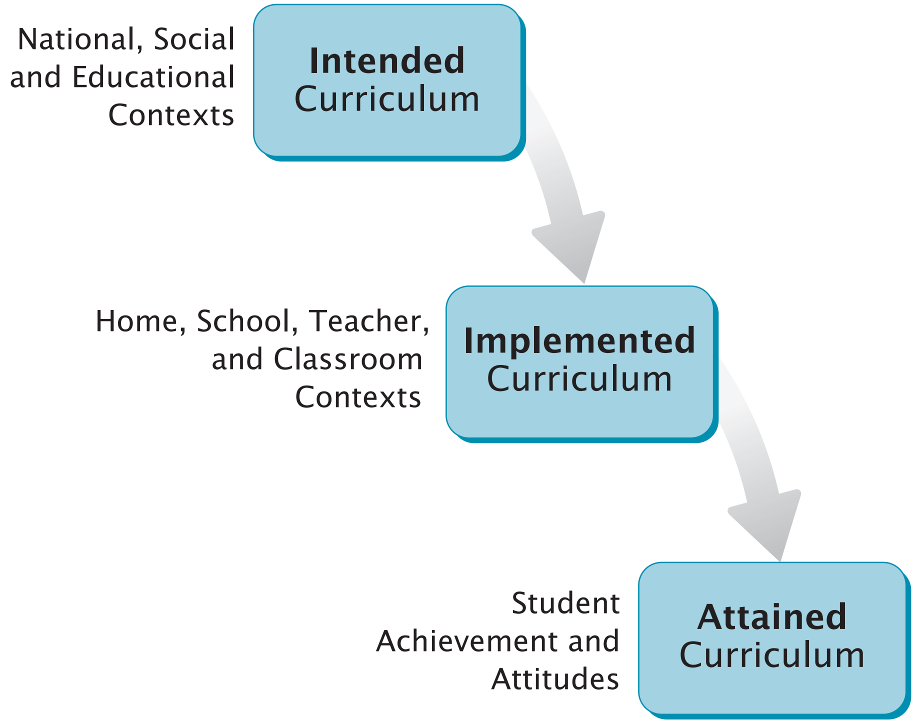
IEA is an independent international cooperative of national research institutions and government agencies that has been conducting studies of cross-national achievement since 1959. IEA pioneered international comparative assessment of educational achievement in the 1960s to gain a deeper understanding of policy effects across countries' different systems of education. Today, IEA's Amsterdam office manages country participation in a number of international studies, and IEA's Hamburg division is a large data processing and research center. As a major program of IEA, TIMSS has the benefit of drawing on the cooperative expertise provided by representatives from countries all around the world.

TIMSS is directed by the TIMSS & PIRLS International Study Center in the Lynch School of Education at Boston College. TIMSS and PIRLS (Progress in International Reading Literacy Study), an international assessment of reading, together comprise IEA's core cycle of studies measuring achievement in three fundamental subjects—mathematics, science, and reading.

Policy Relevant Data About the Content and Contexts for Learning Mathematics and Science

TIMSS uses the curriculum, broadly defined, as the major organizing concept in considering how educational opportunities are provided to students and the factors that influence how students use these opportunities. The TIMSS Curriculum Model has three aspects: the intended curriculum, the implemented curriculum, and the attained curriculum (see Exhibit 1). These represent, respectively, the mathematics and science that students are expected to learn as defined by countries' curriculum policies and publications and how the educational system should be organized to facilitate this learning; what is actually taught in classrooms, the characteristics of those teaching it, and how it is taught; and, finally, what it is that students have learned and what they think about learning these subjects.

Exhibit 1: TIMSS Curriculum Model



Working from this model, TIMSS routinely publishes the TIMSS Encyclopedia with each assessment to document education policies and the curriculum in mathematics and science in each of the participating countries. The *TIMSS 2015 Encyclopedia: Education Policy and Curriculum in Mathematics and Science* (Mullis, Martin, Goh, & Cotter, 2016) provides an important resource for helping to understand the teaching and learning of mathematics and science around the world, with particular emphasis on schooling through the eighth grade. A chapter prepared by each country and benchmarking participant summarizes the structure of its education system, the mathematics and science curricula instruction in the primary and secondary grades, the teacher education requirements, and the types of examinations and assessments employed. To provide standard information across countries that supplements the chapters, countries complete a curriculum questionnaire about their mathematics and science curricula, school organizational approaches, and instructional practices.

TIMSS also asks students, their parents or caregivers, their teachers, and their school principals to complete questionnaires about their home and school experiences and instructional contexts for learning mathematics and science. The questionnaires are developed according to a carefully developed framework that is updated with each assessment through iterative reviews by the TIMSS National Research Coordinators and the TIMSS Questionnaire Item Review Committee of international experts. Data from these questionnaires provide a dynamic picture of the implementation of educational policies and practices that can raise important issues and suggest avenues for educational improvement.

Chapter 3 of this volume contains the TIMSS 2019 Context Questionnaire Framework. TIMSS 2019 will concentrate on measuring trends for the existing context questionnaire scales and developing several new context questionnaire scales that address emerging areas of research in educational effectiveness.

The TIMSS International Assessments in Mathematics and Science

The TIMSS international assessments of mathematics and science were inaugurated in 1995 as a follow-up to IEA's earlier studies conducted separately in these curriculum areas (two in mathematics and two in science) during the 1960s through the 1980s. After the early assessment cycles in the 1990s, TIMSS has been stable over the next two decades with regular assessments every four years at the fourth and eighth grades. Since 1995, the achievement results of each TIMSS assessment (mathematics and science, fourth and eighth grades) have been reported on achievement scales that span the assessment cycles, making it possible to detect changes in achievement from one cycle to the next, and to measure trends in achievement over time. In addition, assessing fourth and eighth grades provides a quasi-cohort design with the fourth grade student cohort assessed in one cycle becoming the eighth grade student cohort assessed in the next cycle. This enables TIMSS to provide valuable information about trends in educational achievement across time and across grades within a particular assessment.

There also are periodic assessments of TIMSS Advanced. First conducted in 1995 and then again in 2008, TIMSS Advanced was recently assessed again as part of TIMSS 2015. It targets students who are engaged in advanced mathematics and physics studies that prepare them to enter STEM (science, technology, engineering, and mathematics) programs in higher education. TIMSS Advanced assesses these students in their final year of secondary school, and is the only international assessment that provides essential information about students specifically prepared for STEM careers.

All of the countries, institutions, and agencies involved in the TIMSS assessments have worked collaboratively in building the most comprehensive, innovative, and stable trend measures of mathematics and science achievement possible. The TIMSS & PIRLS International Study Center, IEA Amsterdam, IEA Hamburg, and the participating countries have worked together to make continual enhancements to TIMSS over its long history of development. For example, in 2011 TIMSS and PIRLS were assessed together to study the relative impact of mathematics, science, and reading achievement at the fourth grade. In 2015, to celebrate 20 years of trends TIMSS and TIMSS Advanced were assessed together for the first time since 1995, providing a profile of education through secondary school. Now, for 2019, TIMSS is starting the transition to a digital format (see the section eTIMSS: The Future of TIMSS).

Taken together, TIMSS' focus on regular assessments measuring trends in achievement, attention to emerging issues in content and the contexts for learning, and robust methods and procedures make it important to educational decision making in the participating countries.

The TIMSS achievement data in combination with the context questionnaire scales can be used to:

- Monitor system-level achievement trends in a global context
- Use TIMSS results to inform educational policy, and monitor the impact of new or revised policies
- Pinpoint any underperforming areas, and stimulate curriculum reform
- See how the fourth grade cohort from a previous cycle performs at the eighth grade in the next cycle
- Obtain important information about the home and school contexts for teaching and learning in relation to students' achievement in mathematics and science

The TIMSS 2019 Assessment Frameworks

Chapters 1 and 2 of this volume contain the TIMSS 2019 Assessment Frameworks for mathematics and science, respectively.

The TIMSS assessments are conducted according to mathematics and science assessment frameworks that have been updated with each assessment throughout TIMSS' 24 year history. The frameworks are organized around two dimensions: a content dimension specifying the subject matter to be assessed and a cognitive dimension specifying the thinking processes to be assessed as students engage with the content.

TIMSS 2019 will follow the usual practice of conducting assessments at the fourth and eighth grades. The *TIMSS 2019 Assessment Frameworks* for these assessments are summarized briefly below.

Mathematics Content Domains

- Fourth Grade—Number, Measurement and Geometry, and Data
- Eighth Grade—Number, Algebra, Geometry, Data and Probability

Science Content Domains

- Fourth Grade—Life Science, Physical Science, Earth Science
- Eighth Grade—Biology, Chemistry, Physics, Earth Science

Cognitive Domains in Mathematics and Science

- Fourth and Eighth Grades—Knowing, Applying, and Reasoning

It is important to emphasize that the items in each TIMSS assessment cover a range of thinking skills, including students' abilities to apply what they have learned, solve problems, and use analysis and logical thinking to reason through situations. As noted above, the three cognitive domains are the same for mathematics and science and for both grades, encompassing a range of cognitive processes involved in learning mathematics and science concepts, and then applying these concepts and reasoning with them. TIMSS Science also integrates science practices across domains, including skills from daily life and school studies that students use in systematic ways to conduct the scientific inquiry that is fundamental to all science disciplines.

The TIMSS assessment frameworks for 2019 were updated from those used in 2015 to provide participating countries opportunities to introduce fresh ideas and current information about curricula, standards, frameworks, and instruction in mathematics and science. The updating process keeps the frameworks educationally relevant, creates coherence from assessment to assessment, and permits the TIMSS frameworks, instruments, and procedures to evolve gradually into the future.

For TIMSS 2019, the TIMSS & PIRLS International Study Center prepared the initial draft based on information from the *TIMSS 2015 Encyclopedia* (Mullis, Martin, Goh, & Cotter, 2016) and reviews provided by the TIMSS 2019 expert group, the Science and Mathematics Item Review Committee (SMIRC), whose members are listed in Appendix A. The updates were discussed by the TIMSS 2019 National Research Coordinators (NRCs) at their first meeting. Each participating country identified an NRC to work with the international project staff to ensure that the assessments are responsive to the country's concerns. Following the discussion at the first NRC meeting, the NRCs consulted with national experts and responded to a topic by topic survey about how best to update the content and cognitive domains for TIMSS 2019. The results of the survey were used to create another draft that was further reviewed and refined by SMIRC. Using an iterative process, the penultimate drafts were once again reviewed by the NRCs as part of their second meeting for TIMSS 2019 and updated a final time prior to publication.

eTIMSS: The Future of TIMSS

TIMSS 2019 will begin the transition to conducting the assessments in the eTIMSS digital format. eTIMSS will provide enhanced measurement of the TIMSS mathematics and science frameworks and take advantage of efficiencies provided by the IEA eAssessment systems. It is anticipated that about half the countries participating in TIMSS 2019 will transition to administering the assessment via computer. The rest of the countries will administer TIMSS in a paper and pencil format as in previous assessments.

To provide extended coverage of the mathematics and science frameworks, eTIMSS 2019 will include additional innovative problem solving and inquiry tasks, known as PSIs. The PSIs simulate real world and laboratory situations where students can integrate and apply process skills and content knowledge to solve mathematics problems and conduct scientific experiments or investigations. The PSI tasks—such as design a building or study plants' growing conditions—involve visually attractive, interactive scenarios that present students with adaptive and responsive ways to follow a series of steps toward a solution. According to early pilot efforts, students find the PSIs engaging and motivating. Also, there will be an opportunity digitally to track students' problem solving or inquiry paths through the PSIs. Studying the process data about what student approaches are successful or unsuccessful in solving problems may provide information to help improve instruction.

It should be emphasized that the demanding criteria for the PSIs make them very difficult and resource intensive to develop. Special teams of consultants as well as the TIMSS 2019 SMIRC members have collaborated virtually and in meetings to develop tasks that: 1) assess mathematics and science (not reading or perseverance), 2) take advantage of the "e" environment, and 3) are engaging and motivating for students.

To support the transition to eTIMSS, IEA Hamburg is developing eAssessment systems to increase operational efficiency in item development, translation and translation verification, assessment delivery, data entry, and scoring. The eTIMSS infrastructure will include: the eTIMSS Item Builder to enter the achievement items, an online translation system to support translation and verification, the eTIMSS Player to deliver the assessment and record students' responses, an online Data Monitor to track data collection, and an online scoring system to facilitate national centers' work in managing and implementing scoring of students' constructed responses.

eTIMSS also includes new digitally based ways for students to respond to constructed response items, which will enable students' responses to many items to be scored by computer rather than "human" scored. In particular, a number keypad enables students to enter the answers to many constructed response mathematics items, such that the answers can be computer scored. Other types of constructed response items that can be computer scored use the drag and drop or sorting functions to answer questions about classifications or measurements.

Design considerations for TIMSS 2019 and eTIMSS 2019 are described in Chapter 4: TIMSS 2019 Assessment Design.

Less Difficult TIMSS Mathematics at Fourth Grade

By their fourth year of schooling, many children have graduated from basic arithmetic and are studying the broader domains and concepts of mathematics. For a variety of reasons, however, there are countries where most children in the fourth grade are still developing fundamental numeracy skills. Thus, beginning in 2015 and continuing in 2019, IEA has extended TIMSS by offering a less difficult mathematics assessment at the fourth grade.

The purpose of including less difficult items was to extend the TIMSS mathematics achievement scale at fourth grade to provide better measurement at the lower end of the scale. In 2015, the less difficult mathematics items, known as TIMSS Numeracy, were given as a separate mathematics assessment, although most countries that participated in TIMSS Numeracy also participated in TIMSS, as usual, to have science results. This led to several important developments. First, TIMSS 2015 was able to report all fourth grade mathematics results on the same achievement scale whether the students participated in TIMSS, TIMSS Numeracy, or both. In turn, this enables TIMSS 2019 to have two versions of TIMSS—one with less difficult mathematics—so that countries do not have to administer two different assessments in order to assess both numeracy and science. Depending on a country's educational development and the students' mathematics proficiency, countries can participate in either version of TIMSS to conduct the most effective assessment.

It is important to understand that for TIMSS 2019 at the fourth grade:

- Both versions of the mathematics assessment, regular and less difficult, were developed according to the fourth grade mathematics framework contained in this volume (see Chapter 1)

- The availability of two versions of TIMSS mathematics at fourth grade enables TIMSS to target the assessment to each country's situation in order to provide the best possible measurement
- The mathematics results for all countries participating in TIMSS 2019 will be reported on the same achievement scale, including the results for countries administering the less difficult version of TIMSS mathematics

Both regular and less difficult versions of TIMSS mathematics at fourth grade are equivalent in scope, and about one-third of the items are the same. The other two-thirds of the items are based on the same areas of the framework, but with those in the less difficult version being generally less difficult. A substantial portion of the items in the less difficult version are from TIMSS Numeracy 2015 to enable measuring trends. The items in common between the two versions of mathematics at fourth grade will enable the two assessments to be linked, so that the results can be reported together and directly compared.

It is important to have a good match between TIMSS and the students' curriculum and achievement. Experience with TIMSS Numeracy and PIRLS Literacy (the less difficult version of IEA's PIRLS reading assessment) indicates that lower performing students are more strongly motivated by less difficult items, and better able to demonstrate what they know and can do, resulting in fewer omitted items, especially for constructed response questions, and higher completion rates.

Introducing LaNA—IEA's Literacy and Numeracy Assessment for Developing Countries

Considering increased efforts to raise literacy and numeracy levels in many countries around the world, IEA has developed an assessment specifically for countries where many students' reading and numeracy skills are emerging but not fully developed. LaNA's literacy and numeracy assessments reflect the same concept of reading and mathematics as PIRLS and TIMSS, respectively, except they are less difficult and designed to assess basic skills that are prerequisites for PIRLS and TIMSS. LaNA is a stepping stone to participating in PIRLS and TIMSS, intended to be responsive to the needs of the global education community and to support efforts that work toward universal learning for all. As debates shift from access to learning for all toward measuring progress toward learning goals for all, LaNA can be an effective avenue to help countries and international organizations assess students' educational achievement and thereby improve reading and mathematics learning outcomes for young students worldwide.

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IEA TIMSS 2019

CHAPTER 1

TIMSS 2019 Mathematics Framework

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CHAPTER 1

TIMSS 2019 Mathematics Framework

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Overview

All children can benefit from developing strong skills in and a deep understanding of mathematics. Primarily, learning mathematics improves problem solving skills, and working through problems can teach persistence and perseverance. Mathematics is essential in daily life for such activities as counting, cooking, managing money, and building things. Beyond that, many career fields require a strong mathematical foundation, such as engineering, architecture, accounting, banking, business, medicine, ecology, and aerospace. Mathematics is vital to economics and finance, as well as to the computing technology and software development underlying our technologically advanced and information based world.

This chapter presents the assessment frameworks for the two TIMSS 2019 mathematics assessments:

- TIMSS Mathematics—Fourth Grade
- TIMSS Mathematics—Eighth Grade

As described in the Introduction, the TIMSS 2019 Mathematics Frameworks for the fourth and eighth grades build on TIMSS' 24-year history of assessments every four years since 1995, with this being the seventh assessment in the series.

In general, the fourth and eighth grade frameworks are similar to those used in TIMSS 2015. However, there have been minor updates to particular topics to better reflect the curricula, standards, and frameworks of the participating countries as reported in the *TIMSS 2015 Encyclopedia* (Mullis, Martin, Goh, & Cotter, 2016). Also, because TIMSS 2019 focuses on the transition to eTIMSS, the mathematics frameworks have been updated and are appropriate for both digital and paper assessment formats. The goal is to capitalize on the benefits of computer-based assessment to begin incorporating new and better assessment methods, especially in the applying and reasoning domains (see Chapter 4).

Each of the two assessment frameworks for TIMSS 2019 is organized around two dimensions:

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

Exhibit 1.1 shows the target percentage of testing time devoted to each content and cognitive domain for the TIMSS 2019 fourth and eighth grade assessments.

Exhibit 1.1: Target Percentages of the TIMSS 2019 Mathematics Assessment Devoted to Content and Cognitive Domains at the Fourth and Eighth Grades

Fourth Grade

Content Domains	Percentages
Number	50%
Measurement and Geometry	30%
Data	20%

Eighth Grade

Content Domains	Percentages
Number	30%
Algebra	30%
Geometry	20%
Data and Probability	20%

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	40%
Reasoning	20%	25%

The content domains differ for the fourth and eighth grades, reflecting the mathematics widely taught at each grade. There is more emphasis on number at the fourth grade than at the eighth grade. At the eighth grade, two of the four content domains are algebra and geometry. Because these generally are not taught as separable areas in primary school, the introductory or prealgebra topics assessed at the fourth grade are included as part of number. The fourth grade data domain focuses on collecting, reading, and representing data, whereas at the eighth grade it includes more emphasis on interpretation of data, basic statistics, and the fundamentals of probability.

It is important to highlight that TIMSS assesses a range of problem solving situations within mathematics, with about two-thirds of the items requiring students to use applying and reasoning skills. The cognitive domains are the same for both grades, but with a shift in emphasis. Compared to the fourth grade, the eighth grade has less emphasis on the knowing domain and greater emphasis on the reasoning domain.

Following this brief introduction, the chapter begins with the fourth grade content domains, identifying the three main content domains and the assessment topics within each domain. Next, Chapter 1 continues with the description of the TIMSS Mathematics—Eighth Grade content domains and, then, the descriptions of the cognitive domains for both the fourth and eighth grades.

Mathematics Content Domains—Fourth Grade

Exhibit 1.2 shows the TIMSS Mathematics—Fourth Grade content domains and the target percentages of assessment score points devoted to each. Each content domain consists of topic areas, and each topic area in turn includes several topics. Across the fourth grade mathematics assessment, each topic receives approximately equal weight.

Exhibit 1.2: Target Percentages of the TIMSS 2019 Mathematics Assessment Devoted to Content Domains at the Fourth Grade

Fourth Grade Content Domains	Percentages
Number	50%
Measurement and Geometry	30%
Data	20%

Number

Number provides the foundation of mathematics in primary school. The number content domain consists of three topic areas. The fifty percent of the assessment devoted to number is apportioned as follows:

- Whole numbers (25%)
- Expressions, simple equations, and relationships (15%)
- Fractions and decimals (10%)

Whole numbers are the predominant component of the number domain and students should be able to compute with whole numbers of reasonable size as well as use computation to solve problems. Prealgebra concepts also are part of the TIMSS assessment at the fourth grade, including understanding the concept of variable (unknowns) in simple equations, and initial understandings of relationships between quantities. However, because objects and quantities often do not come in whole numbers, it is also important for students to understand fractions and decimals. Students should be able to compare, add, and subtract familiar fractions and decimals to solve problems.

Whole Numbers

1. Demonstrate knowledge of place value (2-digit to 6-digit numbers); represent whole numbers with words, diagrams, number lines, or symbols; order numbers.
2. Add and subtract (up to 4-digit numbers), including computation in simple contextual problems.
3. Multiply (up to 3-digit by 1-digit and 2-digit by 2-digit numbers) and divide (up to 3-digit by 1-digit numbers), including computation in simple contextual problems.
4. Solve problems involving odd and even numbers, multiples and factors of numbers, rounding numbers (up to the nearest ten thousand), and making estimates.
5. Combine two or more properties of numbers or operations to solve problems in context.

Expressions, Simple Equations, and Relationships

1. Find the missing number or operation in a number sentence (e.g., $17 + w = 29$).
2. Identify or write expressions or number sentences to represent problem situations that may involve unknowns.
3. Identify and use relationships in a well-defined pattern (e.g., describe the relationship between adjacent terms and generate pairs of whole numbers given a rule).

Fractions and Decimals

1. Recognize fractions as parts of wholes or collections; represent fractions using words, numbers, or models; compare and order simple fractions; add and subtract simple fractions, including those set in problem situations. (Fractions may have denominators of 2, 3, 4, 5, 6, 8, 10, 12, or 100.)
2. Demonstrate knowledge of decimal place value including representing decimals using words, numbers, or models; compare, order, and round decimals; add and subtract decimals, including those set in problem situations. (Decimals may have one or two decimal places, allowing for computations with money.)

Measurement and Geometry

We are surrounded by objects of different shapes and sizes, and geometry helps us visualize and understand the relationships between shapes and sizes. Measurement is the process of quantifying attributes of objects and phenomena (e.g., length and time).

The two topic areas in measurement and geometry are as follows:

- Measurement (15%)
- Geometry (15%)

At the fourth grade, students should be able to use a ruler to measure length; solve problems involving length, mass, capacity, and time; calculate areas and perimeters of simple polygons; and use cubes to determine volumes. Students should be able to identify the properties and characteristics of lines, angles, and a variety of two- and three-dimensional shapes. Spatial sense is integral to the study of geometry, and students will be asked to describe and draw a variety of geometric figures. They also should be able to analyze geometric relationships and use these relationships to solve problems.

Measurement

1. Measure and estimate lengths (millimeters, centimeters, meters, kilometers); solve problems involving lengths.
2. Solve problems involving mass (gram and kilogram), volume (milliliter and liter), and time (minutes and hours); identify appropriate types and sizes of units and read scales.
3. Solve problems involving perimeters of polygons, areas of rectangles, areas of shapes covered with squares or partial squares, and volumes filled with cubes.

Geometry

1. Identify and draw parallel and perpendicular lines; identify and draw right angles and angles smaller or larger than a right angle; compare angles by size.
2. Use elementary properties, including line and rotational symmetry, to describe, compare, and create common two-dimensional shapes (circles, triangles, quadrilaterals, and other polygons).
3. Use elementary properties to describe and compare three-dimensional shapes (cubes, rectangular solids, cones, cylinders, and spheres) and relate these with their two-dimensional representations.

Data

The explosion of data in today's information society has resulted in a daily bombardment of visual displays of quantitative information. Often the Internet, newspapers, magazines, textbooks, reference books, and articles have data represented in charts, tables, and graphs. Students need to understand that graphs and charts help organize information or categories and provide a way to compare data.

The data content domain consists of two topic areas:

- Reading, interpreting, and representing data (15%)
- Using data to solve problems (5%)

At the fourth grade, students should be able to read and recognize various forms of data displays. Given a simple question, students should be able to collect, organize, and represent the data in graphs and charts to address the question. Students should be able to use data from one or more sources to solve problems.

Reading, Interpreting, and Representing Data

1. Read and interpret data from tables, pictographs, bar graphs, line graphs, and pie charts.
2. Organize and represent data to help answer questions.

Using Data to Solve Problems

1. Use data to answer questions that go beyond directly reading data displays (e.g., solve problems and perform computations using data, combine data from two or more sources, draw conclusions based on data).

Mathematics Content Domains—Eighth Grade

Exhibit 1.3 shows the TIMSS Mathematics—Eighth Grade content domains and the target percentages of assessment score points devoted to each. Each content domain consists of topic areas, and each topic area in turn includes several topics. Across the eighth grade mathematics assessment, each topic receives approximately equal weight.

Exhibit 1.3: Target Percentages of the TIMSS 2019 Mathematics Assessment Devoted to Content Domains at the Eighth Grade

Eighth Grade Content Domains	Percentages
Number	30%
Algebra	30%
Geometry	20%
Data and Probability	20%

Number

At the eighth grade, the thirty percent of the assessment devoted to number consists of three topic areas:

- Integers (10%)
- Fractions and decimals (10%)
- Ratio, proportion, and percent (10%)

Building on the number content domain at the fourth grade, eighth grade students should have developed proficiency with more advanced whole number concepts and procedures as well as extended their mathematical understanding of rational numbers (integers, fractions, and decimals). Students also should understand and be able to compute with integers. Fractions and decimals are an important part of daily life and being able to compute with them requires an understanding of the quantities the symbols represent. Students should understand that fractions and decimals are single entities like whole numbers. A single rational number can be represented with many different written symbols, and students need to be able to recognize the distinctions among interpretations of rational numbers, convert between them, and reason with them. Students should be able to solve problems involving ratios, proportions, and percents.

Integers

1. Demonstrate understanding of properties of numbers and operations; find and use multiples and factors, identify prime numbers, evaluate positive integer powers of numbers, evaluate square roots of perfect squares up to 144, and solve problems involving square roots of whole numbers.
2. Compute and solve problems with positive and negative numbers, including through movement on the number line or various models (e.g., losses and gains, thermometers).

Fractions and Decimals

1. Using various models and representations, compare and order fractions and decimals, and identify equivalent fractions and decimals.
2. Compute with fractions and decimals, including those set in problem situations.

Ratio, Proportion, and Percent

1. Identify and find equivalent ratios; model a given situation by using a ratio; divide a quantity according to a given ratio.
2. Solve problems involving proportions or percents, including converting between percents and fractions or decimals.

Algebra

The thirty percent of the assessment devoted to algebra is comprised of two topic areas:

- Expressions, operations, and equations (20%)
- Relationships and functions (10%)

Patterns and relationships are pervasive in the world around us and algebra enables us to express these mathematically. Students should be able to solve real world problems using algebraic models and explain relationships involving algebraic concepts. They need to understand that when there is a formula involving two quantities, if they know one quantity, they can find the other either algebraically or by substitution. This conceptual understanding can extend to linear equations for calculations about things that expand at constant rates (e.g., slope). Functions can be used to describe what will happen to a variable when a related variable changes.

Expressions, Operations, and Equations

1. Find the value of an expression or a formula given values of the variables.
2. Simplify algebraic expressions involving sums, products, and powers; compare expressions to determine if they are equivalent.
3. Write expressions, equations, or inequalities to represent problem situations.
4. Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations.

Relationships and Functions

1. Interpret, relate and generate representations of linear functions in tables, graphs, or words; identify properties of linear functions including slope and intercepts.
2. Interpret, relate and generate representations of simple non-linear functions (e.g., quadratic) in tables, graphs, or words; generalize pattern relationships in a sequence using numbers, words, or algebraic expressions.

Geometry

Extending the understanding of shapes and measures assessed at the fourth grade, eighth grade students should be able to analyze the properties of a variety of two- and three-dimensional figures and calculate perimeters, areas, and volumes. They should be able to solve problems and provide explanations based on geometric relationships, such as congruence, similarity, and the Pythagorean theorem.

The geometry content domain at the eighth grade consists of one topic area:

- Geometric shapes and measurements (20%)

Geometric Shapes and Measurements

At eighth grade, geometric shapes include circles; scalene, isosceles, equilateral, and right-angled triangles; trapezoids, parallelograms, rectangles, rhombuses, and other quadrilaterals; as well as other polygons including pentagons, hexagons, octagons, and decagons. They also include three-dimensional shapes—prisms, pyramids, cones, cylinders, and spheres. One- and two-dimensional figures can be presented in the Cartesian plane.

1. Identify and draw types of angles and pairs of lines and use the relationships between angles on lines and in geometric figures to solve problems, including those involving the measures of angles and line segments; solve problems involving points in the Cartesian plane.
2. Identify two-dimensional shapes and use their geometric properties to solve problems, including those involving perimeter, circumference, area, and the Pythagorean Theorem.

3. Recognize and draw images of geometric transformations (translations, reflections, and rotations) in the plane; identify congruent and similar triangles and rectangles and solve related problems.

4. Identify three-dimensional shapes and use their geometric properties to solve problems, including those involving surface area and volume; relate three-dimensional shapes with their two-dimensional representations.

Data and Probability

Increasingly, the more traditional forms of data display (e.g., bar graphs, line graphs, pie graphs, pictographs) are being supplemented by an array of new graphic forms (e.g., infographics). By the eighth grade, students should to be able to read and extract the important meaning from a variety of visual displays. It is also important for eighth grade students to be familiar with the statistics underlying data distributions and how these relate to the shape of data graphs. Students should know how to collect, organize, and represent data. Students also should have an initial grasp of some concepts related to probability.

The data and probability content domain contains two topic areas:

- Data (15%)
- Probability (5%)

Data

1. Read and interpret data from one or more sources to solve problems (e.g., interpolate and extrapolate, make comparisons, draw conclusions).

2. Identify appropriate procedures for collecting data; organize and represent data to help answer questions.

3. Calculate, use, or interpret statistics (i.e., mean, median, mode, range) summarizing data distributions; recognize the effect of spread and outliers.

Probability

1. For simple and compound events: a) determine theoretical probability (based on equally likely outcomes, e.g., rolling a fair die) or b) estimate the empirical probability (based on experimental outcomes).

Calculator Use at the Eighth Grade

Continuing the practice of previous TIMSS assessments, at the fourth grade students will not be permitted to use calculators. This includes both paperTIMSS and eTIMSS. At the eighth grade, students will be permitted to use calculators, although the mathematics items are developed to be calculator neutral–do not advantage or disadvantage students whether or not they have calculators. In paperTIMSS, consistent with past TIMSS assessments, students at the eighth grade may bring their own calculators to the assessment. In eTIMSS, students at the eighth grade will have access to a calculator provided as part of the on-screen interface and will not be permitted to bring their own calculators. The on-screen calculator includes the four basic functions (+ , − , ×, ÷) and a square root key. The eventual transition to eTIMSS will result in calculators being standardized.

Mathematics Cognitive Domains—Fourth and Eighth Grades

In order to respond correctly to TIMSS test items, students need to be familiar with the mathematics 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 2019, because they are vital in ensuring that the survey covers the appropriate range of cognitive skills across the content domains already outlined.

The first domain, *knowing*, covers the facts, concepts, and procedures students need to know, while the second, *applying*, focuses on the ability of students to apply knowledge and conceptual understanding to solve problems or answer questions. The third domain, *reasoning*, goes beyond the solution of routine problems to encompass unfamiliar situations, complex contexts, and multistep problems.

Knowing, applying, and reasoning are exercised in varying degrees when students display their mathematical competency, which goes beyond content knowledge. These TIMSS cognitive domains encompass the competencies of problem solving, providing a mathematical argument to support a strategy or solution, representing a situation mathematically (e.g., using symbols and graphs), creating mathematical models of a problem situation, and using tools such as a ruler or a calculator to help solve problems.

The three cognitive domains are used for both grades, but the balance of testing time differs, reflecting the difference in age and experience of students in the two grades. For the fourth and eighth grades, each content domain will include items developed to address each of the three cognitive domains. For example, the number domain will include knowing, applying, and reasoning items as will the other content domains.

Exhibit 1.4 shows the target percentages of testing time devoted to each cognitive domain for the fourth and eighth grade assessments.

Exhibit 1.4: Target Percentages of the TIMSS 2019 Mathematics Assessment Devoted to Cognitive Domains at the Fourth and Eighth Grades

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	40%
Reasoning	20%	25%

Knowing

Facility in applying mathematics, or reasoning about mathematical situations, depends on familiarity with mathematical concepts and fluency in mathematical skills. The more relevant knowledge a student is able to recall and the wider the range of concepts he or she understands, the greater the potential for engaging in a wide range of problem solving situations.

Without access to a knowledge base that enables easy recall of the language and basic facts and conventions of number, symbolic representation, and spatial relations, students would find purposeful mathematical thinking impossible. Facts encompass the knowledge that provides the basic language of mathematics, as well as the essential mathematical concepts and properties that form the foundation for mathematical thought.

Procedures form a bridge between more basic knowledge and the use of mathematics for solving problems, especially those encountered by many people in their daily lives. In essence, a fluent use of procedures entails recall of sets of actions and how to carry them out. Students need to be efficient and accurate in using a variety of computational procedures and tools. They need to see that particular procedures can be used to solve entire classes of problems, not just individual problems.

Recall	Recall definitions, terminology, number properties, units of measurement, geometric properties, and notation (e.g., $a \times b = ab$, $a + a + a = 3a$).
Recognize	Recognize numbers, expressions, quantities, and shapes. Recognize entities that are mathematically equivalent (e.g., equivalent familiar fractions, decimals, and percents; different orientations of simple geometric figures).
Classify/Order	Classify numbers, expressions, quantities, and shapes by common properties.
Compute	Carry out algorithmic procedures for $+$, $-$, $\times$, $\div$, or a combination of these with whole numbers, fractions, decimals, and integers. Carry out straightforward algebraic procedures.
Retrieve	Retrieve information from graphs, tables, texts, or other sources.
Measure	Use measuring instruments; and choose appropriate units of measurement.

Applying

The applying domain involves the application of mathematics in a range of contexts. In this domain, the facts, concepts, and procedures as well as the problems should be familiar to the student. In some items aligned with this domain, students need to apply mathematical knowledge of facts, skills, and procedures or understanding of mathematical concepts to create representations. Representation of ideas forms the core of mathematical thinking and communication, and the ability to create equivalent representations is fundamental to success in the subject.

Problem solving is central to the applying domain, with an emphasis on more familiar and routine tasks. Problems may be set in real life situations, or may be concerned with purely mathematical questions involving, for example, numeric or algebraic expressions, functions, equations, geometric figures, or statistical data sets.

Determine	Determine efficient/appropriate operations, strategies, and tools for solving problems for which there are commonly used methods of solution.
Represent/Model	Display data in tables or graphs; create equations, inequalities, geometric figures, or diagrams that model problem situations; and generate equivalent representations for a given mathematical entity or relationship.
Implement	Implement strategies and operations to solve problems involving familiar mathematical concepts and procedures.

Reasoning

Reasoning mathematically involves logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to problems set in novel or unfamiliar situations. Such problems may be purely mathematical or may have real life settings. Both types of items involve transferring knowledge and skills to new situations; and interactions among reasoning skills usually are a feature of such items.

Even though many of the cognitive skills listed in the reasoning domain may be drawn on when thinking about and solving novel or complex problems, each by itself represents a valuable outcome of mathematics education, with the potential to influence learners' thinking more generally. For example, reasoning involves the ability to observe and make conjectures. It also involves making logical deductions based on specific assumptions and rules, and justifying results.

Analyze	Determine, describe, or use relationships among numbers, expressions, quantities, and shapes.
Integrate/Synthesize	Link different elements of knowledge, related representations, and procedures to solve problems.
Evaluate	Evaluate alternative problem solving strategies and solutions.
Draw Conclusions	Make valid inferences on the basis of information and evidence.
Generalize	Make statements that represent relationships in more general and more widely applicable terms.
Justify	Provide mathematical arguments to support a strategy or solution.

References

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TIMSS

2019

CHAPTER 2

TIMSS 2019 Science Framework

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TIMSS & PIRLS
International Study Center
Lynch School of Education
BOSTON COLLEGE

CHAPTER 2

TIMSS 2019 Science Framework

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Overview

Children have a natural curiosity about the world and their place in it. Science education in the primary grades capitalizes on this curiosity and starts young students on a path of systematic inquiry about the world in which they live. As their understanding of science develops, students in the lower-secondary grades become increasingly able to make informed decisions about themselves and their world so that, as adults, they can become informed citizens capable of distinguishing scientific fact from fiction and understanding the scientific basis of important social, economic, and environmental issues. Across the world, there is an increased demand for those qualified to pursue the careers in science, technology, and engineering that drive the innovation necessary for economic growth and for improving quality of life. To meet this demand, it is increasingly important to prepare students to enter advanced study in these areas.

This chapter presents the assessment frameworks for the two TIMSS 2019 science assessments:

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

The TIMSS 2019 Science Frameworks for the fourth and eighth grades extend the 24-year history of TIMSS assessments, beginning in 1995 and taking place every four years since. TIMSS 2019 is the seventh assessment in the series.

In general, the TIMSS 2019 science frameworks are similar to those used in TIMSS 2015. However, there have been minor updates to particular topics to better reflect the curricula of the participating countries as reported in the *TIMSS 2015 Encyclopedia* (Mullis, Martin, Goh, and Cotter, 2016). TIMSS 2019 marks the transition to eTIMSS, and the science frameworks have also been updated to take advantage of both digital and paper assessment formats. eTIMSS provides an avenue for expanding the range of assessment methods included in TIMSS and capitalizes especially on new and improved computer-based approaches to the assessment of inquiry and investigation in science.

At each grade, the science assessment framework for TIMSS 2019 is organized around two dimensions:

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

Exhibit 2.1 shows the target percentage of testing time devoted to each content and cognitive domain for the TIMSS 2019 fourth and eighth grade assessments.

Exhibit 2.1: Target Percentages of the TIMSS 2019 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	Percentages	
	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 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 (knowing, applying, and reasoning) are the same at both grades, encompassing the range of cognitive processes involved in learning science concepts, and then applying these concepts and reasoning with them.

In 2019, 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 investigation 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 (Mullis, Martin, Goh, and Cotter, 2016).

The practice of science is, by its very nature, strongly connected to the area of science under study and, therefore, cannot be assessed in isolation. Some items in the TIMSS 2019 science assessment at both the fourth and eighth grades will assess one or more of these important science practices together with content specified in the content domains and thinking processes specified in the cognitive domains.

The next two sections of this chapter present the TIMSS 2019 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.

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 2.2 shows the target percentages of testing time for each of the three content domains in the TIMSS 2019 Science assessment.

Exhibit 2.2: Target Percentages of the TIMSS 2019 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 several major topic areas, and each topic area in turn includes one or more topics. Each topic is further described by specific objectives that represent the students' expected knowledge, abilities, and skills assessed within each topic. Across the fourth grade assessment, each objective receives approximately equal weight in terms of the number of assessment items. The verbs used in the objectives are intended to represent typical performances expected of fourth grade students, but are not intended to limit performances to a particular cognitive domain. Each objective can be assessed drawing on any of the three cognitive domains (knowing, applying, and reasoning).

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. In TIMSS 2019, 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
- Human health

By the fourth grade, students are expected to be building a base of knowledge about general characteristics of organisms, how they function, and how they interact with other organisms and with their environment. Students also should be familiar with fundamental science concepts related to life cycles, heredity, and human health that in later grades will lead to a more sophisticated understanding of how the human body functions.

Characteristics and Life Processes of Organisms

1. Differences between living and non-living things and what living things require to live:
   - A. Recognize and describe differences between living and non-living things (i.e., all living things can reproduce, grow and develop, respond to stimuli, and die; and non-living things cannot).
   - B. Identify what living things require in order to live (i.e., 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 major groups of living things (i.e., insects, birds, mammals, fish, reptiles, and flowering plants).
   - B. Identify or provide examples of members of major groups of living things (i.e., insects, birds, mammals, fish, reptiles, 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 (e.g., teeth break down food, bones support the body, lungs take in air, the heart circulates blood, the stomach digests food, muscles move the body).
   - B. Relate major structures in plants to their functions (i.e., roots absorb water and nutrients and anchor the plant, leaves make food, the stem transports water and food, petals attract pollinators, flowers produce seeds, and seeds produce new plants).

Life Cycles, Reproduction, and Heredity

1. Stages of life cycles and differences among the life cycles of common plants and animals:
   - A. Identify stages of the life cycles of plants (i.e., germination, growth and development, reproduction, and seed dispersal).
   - B. Recognize, compare, and contrast the life cycles of familiar plants and animals (e.g., trees, beans, humans, frogs, 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.
   - B. Distinguish between features of plants and animals that are inherited from their parents (e.g., number of petals, color of petals, eye color, hair color), and those that are not (e.g., some broken branches in a tree, length of human hair).
   - C. Identify and describe different strategies that increase the number of offspring that survive (e.g., a plant producing many seeds, mammals caring for their young).

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 and describe how these features help them to survive (e.g., a thick stem, a waxy coating, and a deep root help a plant survive in an environment with little water; the coloring of an animal helps camouflage it from predators).
   - B. Associate behaviors of animals with the environments in which they live and describe how these behaviors help them to survive (e.g., migration or hibernation helps an animal to stay alive when food is scarce).
2. Responses of living things to environmental conditions:
   - A. Recognize and describe how plants respond to environmental conditions (e.g., amount of available water, amount of sunlight).
   - B. Recognize and describe how different animals respond to changes in environmental conditions (e.g., light, temperature, danger); recognize and describe how the human body responds to high and low temperatures, exercise, and danger.
3. The impact of humans on the environment:
   - A. Recognize that human behavior has negative and positive effects on the environment (e.g., negative effects of air and water pollution, the benefits of reducing air and water pollution); provide general descriptions and examples of the effects of pollution on humans, plants, and animals, and their environments.

Ecosystems

1. Common ecosystems:

   A. Relate common plants and animals (e.g., evergreen trees, frogs, lions) to common ecosystems (e.g., forests, ponds, grasslands).

2. Relationships in simple food chains:

   A. Recognize that all plants and animals need food to provide energy for activity and need raw materials for growth and repair; explain that plants need sunlight to make their food, while animals eat plants or other animals to get their food.

   B. Complete a model of a simple food chain using common plants and animals from familiar ecosystems, such as a forest or a desert.

   C. Describe the roles of living things at each link in a simple food chain (e.g., plants produce their own food; some animals eat plants, while other animals eat the animals that eat plants).

   D. Identify and describe common predators and their prey.

3. Competition in ecosystems:

   A. Recognize and explain that some living things in an ecosystem compete with others for food or space.

Human Health

1. Transmission, prevention, and symptoms of communicable diseases:

   A. Relate the transmission of common communicable diseases to human contact (e.g., touching, sneezing, coughing).

   B. Identify or describe some methods of preventing disease transmission (e.g., vaccination, washing hands, avoiding people who are sick); recognize common signs of illness (e.g., high body temperature, coughing, stomachache).

2. Ways of maintaining good health:

   A. Describe everyday behaviors that promote good health (e.g., a balanced diet, exercising regularly, brushing teeth, getting enough sleep, wearing sunscreen); identify common food sources included in a balanced diet (e.g., fruits, vegetables, grains).

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 are:

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

Fourth grade students should have an understanding of physical states of matter (solid, liquid, and gas), 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.

Classification and Properties of Matter and Changes in Matter

1. States of matter and characteristic differences of each state:
   A. Identify and describe three states of matter (i.e., a solid has a definite shape and volume, a liquid has a definite volume but not a definite shape, and a gas has neither a definite shape nor a definite volume).
2. Physical properties as a basis for classifying matter:
   A. Compare and sort objects and materials on the basis of physical properties (e.g., weight/mass, volume, state of matter, ability to conduct heat or electricity, ability to float or sink in water, ability to be attracted by a magnet). [Note: Students in the fourth grade are not expected to differentiate between mass and weight.]
   B. Identify properties of metals (i.e., conducting electricity and conducting heat) and relate these properties to uses of metals (e.g., a copper electrical wire, an iron cooking pot).
   C. Describe examples of mixtures and how they can be physically separated (e.g., sifting, filtration, evaporation, magnetic attraction).
3. Magnetic attraction and repulsion:
   A. Recognize that magnets have two poles and that like poles repel and opposite poles attract.
   B. Recognize that magnets can be used to attract some metal objects.
4. Physical changes observed in everyday life:
   A. Identify observable changes in materials that do not result in new materials with different properties (e.g., dissolving, crushing an aluminum can).
   B. Recognize that matter can be changed from one state to another by heating or cooling; describe changes in the state of water (i.e., melting, freezing, boiling, evaporation, and condensation).

C. Identify ways of increasing how quickly a solid material dissolves in a given amount of water (i.e., increasing the temperature, stirring, and breaking the solid into smaller pieces); distinguish between strong and weak concentrations of simple solutions.

5. Chemical changes observed in everyday life:

   A. Identify observable changes in materials that make new materials with different properties (e.g., decaying, such as food spoiling; burning; rusting).

Forms of Energy and Energy Transfer

1. Common sources and uses of energy:

   A. Identify sources of energy (e.g., the Sun, flowing water, wind, coal, oil, gas), and recognize that energy is needed to move objects and for heating and lighting.

2. Light and sound in everyday life:

   A. Relate familiar physical phenomena (i.e., shadows, reflections, and rainbows) to the behavior of light.

   B. Relate familiar physical phenomena (i.e., vibrating objects and echoes) to the production and behavior of sound.

3. Heat transfer:

   A. Recognize that warmer objects have a higher temperature than cooler objects; describe what will happen when a hot object and a cold object are brought into contact (i.e., the temperature of the hot object decreases and the temperature of the cold object increases).

4. Electricity and simple electrical systems:

   A. Recognize that electrical energy in a circuit can be transformed into other forms of energy (e.g., heat, light, sound).

   B. Explain that simple electrical systems (e.g., a flashlight) require a complete (unbroken) electrical pathway.

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 (i.e., pushing and pulling) may cause an object to change its motion; compare the effects of these forces of different strengths in the same or opposite directions acting on an object; and recognize that friction force works against the direction of motion (e.g., friction working against a push or a pull makes it more difficult to move an object along a surface).

2. Simple machines:

   A. Recognize that simple machines, (e.g., levers, pulleys, gears, ramps) help make motion easier (e.g., make lifting things easier, reduce the amount of force required, change the distance, change the direction of the force).

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 as they learn about the planet on which they live and its place in the Solar System:

- Earth's physical characteristics, resources, and history
- Earth's weather and climates
- 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's Physical Characteristics, Resources, and History

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; describe where fresh and salt water are found, and recognize that water in rivers or streams flows from mountains to oceans or lakes.

2. Earth's resources:

   A. Identify some of Earth's resources that are used in everyday life (e.g., water, wind, soil, forests, oil, natural gas, minerals).

   B. Explain the importance of using Earth's renewable and non-renewable resources responsibly (e.g., fossil fuels, forests, water).

3. Earth's history:

   A. Recognize that wind and water change Earth's landscape and that some features of Earth's landscape (e.g., mountains, river valleys) result from changes that happen very slowly over a long time.

B. Recognize that some remains (fossils) of animals and plants that lived on Earth a long time ago are found in rocks and make simple deductions about changes in Earth's surface from the location of these remains.

Earth's Weather and Climates

1. Weather and climates on Earth:

   A. Apply knowledge of changes of state of water to common weather events (e.g., cloud formation, dew formation, the evaporation of puddles, snow, rain).

   B. Describe how weather (i.e., daily variations in temperature, humidity, precipitation in the form of rain or snow, clouds, and wind) can vary with geographic location.

   C. Describe how average temperature and precipitation can change with the seasons and location.

Earth in the Solar System

1. Objects in the Solar System and their movements:

   A. Identify the Sun as a source of heat and light for the Solar System; describe the Solar System as the Sun and the planets that revolve around it.

   B. Recognize that the Earth has a moon that revolves around it, and from Earth the Moon looks different at different times of the month.

2. Earth's motion and related patterns observed on Earth:

   A. Explain how day and night are related to Earth's daily rotation about its axis, and provide evidence of this rotation from the changing appearance of shadows during the day.

   B. Describe how seasons in Earth's 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 2.3 shows the target percentages for each of the four content domains in the TIMSS 2019 science assessment.

Exhibit 2.3: Target Percentages of the TIMSS 2019 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 several major topic areas, and each topic area in turn includes one or more topics. Each topic is further described by specific objectives that represent the students' expected knowledge, abilities, and skills assessed within each topic. Across the eighth grade assessment, each objective receives approximately equal weight in terms of assessment items. The verbs used in the objectives are intended to represent typical performances expected of eighth grade students, but are not intended to limit performances to a particular cognitive domain. Each objective can be assessed drawing on each of the three cognitive domains (knowing, applying, and reasoning).

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
- Human health

Concepts learned in each of these topic areas are essential for preparing students for more advanced study. Eighth grade students are expected to understand how structure relates to function in organisms. They also should have a foundational 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 later, 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.

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 (i.e., plants, animals, fungi, mammals, birds, reptiles, fish, amphibians, and insects).
   - B. Recognize and categorize organisms that are examples of major taxonomic groups of organisms (i.e., plants, animals, fungi, mammals, birds, reptiles, fish, amphibians, and insects).
2. Structures and functions of major organ systems:
   - A. Locate and identify major organs (e.g., lungs, stomach, brain) and the components of major organ systems (e.g., respiratory system, digestive system) in the human body.
   - B. Compare and contrast major organs and major organ systems in humans and other vertebrates.
   - C. Explain the role of major organs and major organ systems in sustaining life, such as those involved in circulation and respiration.
3. Physiological processes in animals:
   - A. Recognize responses of animals to external and internal changes that work to maintain stable body conditions (e.g., increased heart rate during exercise, feeling thirsty when dehydrated, feeling hungry when requiring energy, sweating in heat, shivering in cold).

Cells and Their Functions

1. The structures and functions of cells:
   - A. Explain that living things are made of cells that both carry out life functions and reproduce by division.
   - B. Identify major cell structures (i.e., cell wall, cell membrane, nucleus, chloroplast, vacuole, and mitochondria) and describe the primary functions of these structures.
   - C. Recognize that cell walls and chloroplasts differentiate plant cells from animal cells.

D. Explain that tissues, organs, and organ systems are formed from groups of cells with specialized structures and functions.

2. The processes of photosynthesis and cellular respiration:

   A. Describe the basic process of photosynthesis (i.e., requires light, carbon dioxide, water, and chlorophyll; produces glucose/sugar; and releases oxygen).

   B. Describe the basic process of cellular respiration (i.e., requires oxygen and glucose/sugar; produces energy; and releases carbon dioxide and water).

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 (i.e., mammals, birds, amphibians, insects, and plants).

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; relate the inheritance of traits to organisms passing on genetic material to their offspring.

   B. Recognize that an organism's traits are encoded in its DNA; recognize that DNA is genetic information found in chromosomes located in the nucleus of each cell.

   C. Distinguish inherited characteristics from acquired or learned characteristics.

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. 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 recognize that the degree of similarity of characteristics provides evidence of common ancestry.

Ecosystems

1. The flow of energy in ecosystems:
   A. Identify and provide examples of producers, consumers, and decomposers; draw or interpret food web diagrams.
   B. Describe the flow of energy in an ecosystem (i.e., energy flows from producers to consumers, and only part of the energy is passed from one level to the next); draw or interpret energy pyramids.
2. The cycling of water, oxygen, and carbon in ecosystems:
   A. Describe the role of living things in cycling water through an ecosystem (i.e., plants take in water from the soil and give off water through their leaves; and animals take in water and release water during respiration and as waste).
   B. Describe the role of living things in cycling oxygen and carbon through an ecosystem (i.e., plants take in carbon dioxide from the air and release oxygen into the air as part of photosynthesis and store carbon in their cells; and animals take in oxygen from the air and release carbon dioxide into the air as part of respiration).
3. Interdependence of populations of organisms in an ecosystem:
   A. Describe and provide examples of competition among populations or organisms in an ecosystem.
   B. Describe and provide examples of predation in an ecosystem.
   C. Describe and provide examples of symbiosis among populations of organisms in an ecosystem (e.g., birds or insects pollinating flowers, birds eating insects on deer or cattle).
4. Factors affecting population size in an ecosystem:
   A. Describe factors that affect the growth of plants and animals; identify factors that limit population size (e.g., disease, predators, food resources, drought).
   B. Predict how changes in an ecosystem (e.g., changes in the water supply, the introduction of a new population, hunting, migration) can affect available resources, and thus the balance among populations.
5. Human impact on the environment:
   A. Describe and explain ways in which human behavior (e.g., re-planting forests, reducing air and water pollution, protecting endangered species) can have positive effects on the environment.

B. Describe and explain ways in which human behavior (e.g., allowing factory waste water to enter water systems, burning fossil fuels that release greenhouse gases and pollutants into the air) can have negative effects on the environment; describe and provide examples of the effects of air, water, and soil pollution on humans, plants, and animals (e.g., water pollution can reduce plant and animal life in the water system).

Human Health

1. Causes, transmission, and prevention of, and resistance to diseases:

   A. Describe causes, transmission, and prevention of common diseases (e.g., influenza, measles, malaria, HIV).

   B. Describe the role of the body's immune system in resisting disease and promoting healing (i.e., antibodies in the blood help the body resist infection and white blood cells fight infection).

2. The importance of diet, exercise, and other lifestyle choices:

   A. Explain the importance of diet, exercise, and other lifestyle choices in maintaining health and preventing illness (e.g., heart disease, high blood pressure, diabetes, skin cancer, lung cancer).

   B. Identify the dietary sources and roles of nutrients in a healthy diet (i.e., 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 later, more advanced study. The chemistry domain includes three topic areas:

- Composition of matter
- Properties of matter
- Chemical change

The composition of matter topic area focuses on differentiating elements, compounds, and mixtures and understanding the particulate structure of matter. Included in this area also is the use of the periodic table as an organizing principle for the elements. At a more macroscopic level, the properties of matter topic area focuses on distinguishing between physical and chemical properties of matter and understanding the properties of mixtures and solutions and the properties of acids and bases. The study of chemical change focuses on the characteristics of chemical changes and the conservation of matter during chemical changes.

Composition of Matter

1. Structure of atoms and molecules:

   A. Describe atoms as composed of subatomic particles (i.e., negatively charged electrons surrounding a nucleus containing positively charged protons and neutrons with no charge).

   B. Describe the structure of matter in terms of particles (i.e., atoms and molecules) and describe molecules as combinations of atoms (e.g., H_2O, O_2, CO_2).

2. Elements, compounds, and mixtures:

   A. Describe the differences among elements, compounds, and mixtures; differentiate between pure substances (i.e., elements and compounds) and mixtures (homogeneous and heterogeneous) on the basis of their formation and composition.

3. The periodic table of elements:

   A. Recognize that the periodic table is an arrangement of the known elements; recognize and describe that the elements are arranged in order of the number of protons in the nuclei of the atoms of each element.

   B. Recognize that an element's properties (e.g., metal or non-metal, reactivity) can be predicted from its location in the periodic table (i.e., row, or period, and column, or group/family) and that elements in the same group have some properties in common.

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 (e.g., melting point, boiling point, solubility, thermal conductivity).

   C. Relate uses of materials to their chemical properties (e.g., tendency to rust, 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 (e.g., density, melting or boiling point, solubility, magnetic properties, electrical or thermal conductivity).

   B. Classify substances according to their chemical properties (e.g., whether the substance is a metal or a nonmetal).

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) (i.e., solid, liquid, or gas solutes) dissolved in a solvent and relate the concentration of a solution to the amounts of solute and solvent present.

C. Explain how temperature, stirring, and surface area in contact with the solvent affect the rate at which solutes dissolve.

4. Properties of acids and bases:

   A. Recognize everyday substances as acids or bases based on their properties (e.g., acids have pH less than 7; acidic foods usually have a sour taste; bases usually do not react with metals; bases feel slippery).

   B. Recognize that both acids and bases react with indicators to produce different color changes.

   C. Recognize that acids and bases neutralize each other.

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 (i.e., 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 oxidation reactions (i.e., combustion, rusting, and tarnishing) and relate these reactions to everyday activities (e.g., burning wood, preserving metal objects).

2. Matter and energy in chemical reactions:

   A. Recognize that matter is conserved during a chemical reaction and that all of the atoms present at the beginning of the reaction are present at the end of the reaction, but they are rearranged to form new substances.

   B. Recognize that some chemical reactions release energy (heat) while others absorb it, and classify familiar chemical reactions (e.g., burning, neutralization, the mixing of substances in a chemical cold pack) as either releasing heat or absorbing energy (heat).

   C. Recognize that chemical reactions occur at different rates and that the rate of reaction can be affected by changing the conditions under which the reaction is taking place (i.e., surface area, temperature, and concentration).

3. Chemical bonds:

   A. Recognize that a chemical bond results from the attraction 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
- Motion and forces

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

Physical States and Changes in Matter

1. Motion of particles in solids, liquids, and gases:
   A. Recognize that atoms and molecules in matter are in constant motion and recognize the differences in relative motion and distance between particles in solids, liquids, and gases; apply knowledge about the movement of and distance between atoms and molecules to explain the physical properties of solids, liquids, and gases (i.e., volume, shape, density, and compressibility).

   B. Relate changes in temperature 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 changes of state (i.e., melting, freezing, boiling, evaporation, condensation, and sublimation) as resulting from an increase or decrease of thermal energy.
   B. Relate the rate of change of state to physical factors (e.g., surface area, the temperature of the surroundings).
3. Physical changes:
   A. Recognize that physical changes do not involve the formation of new substances.
   B. Explain that mass remains constant during physical changes (e.g., change of state, dissolving solids, thermal expansion).

Energy Transformation and Transfer

1. Forms of energy and the conservation of energy:
   A. Identify different forms of energy (e.g., kinetic, potential, light, sound, electrical, thermal, chemical).
   B. Describe the energy transformations that take place in common processes (e.g., combustion in an engine to move a car, photosynthesis, the production of hydroelectric power); recognize that the total energy of a closed system is conserved.
2. Thermal energy transfer and thermal conductivity of materials:
   A. Recognize that temperature remains constant during melting, boiling, and freezing, but thermal energy increases or decreases during a state change.
   B. Relate the transfer of thermal energy from an object or an area at a higher temperature to one at a lower temperature to cooling and heating; recognize that hot objects cool off and cold objects warm up until they reach the same temperature as their surroundings.
   C. Recognize that conduction, convection, and radiation are all types of thermal energy transfer; compare the relative thermal conductivity of different materials.

Light and Sound

1. Properties of light:
   A. Describe or identify basic properties of light (i.e., speed; transmission through different media; reflection, refraction, absorption, and splitting of white light into its component colors); relate the apparent color of objects to reflected or absorbed light.
   B. Solve practical problems involving the reflection of light from plane mirrors and the formation of shadows; interpret simple ray diagrams to identify the path of light.

2. Properties of sound:

   A. Recognize that sound is a wave phenomenon caused by vibration and is characterized by loudness (amplitude) and pitch (frequency); describe some basic properties of sound (i.e., the need for a medium for transmission, reflection and absorption by surfaces, and relative speed through different media which is always slower than light).

   B. Relate common phenomena (e.g., echoes, hearing thunder after seeing lightning) to the properties of sound.

Electricity and Magnetism

1. Conductors and the flow of electricity in electrical circuits:

   A. Classify materials as electrical conductors or insulators; identify electrical components or materials that can be used to complete circuits.

   B. Identify diagrams representing complete circuits; describe factors that affect electrical current in series or parallel circuits (e.g., the number of batteries and/or bulbs).

2. Properties and uses of permanent magnets and electromagnets:

   A. Relate properties of permanent magnets (i.e., two opposite poles, attraction/repulsion, and strength of the magnetic force varies with distance) to uses in everyday life (e.g., a directional compass).

   B. Describe the properties that are unique to electromagnets (i.e., the strength varies with current, number of coils, and type of metal in the core; the magnetic attraction can be turned on and off; and the poles can switch) and relate properties of electromagnets to uses in everyday life (e.g., doorbell, recycling factory).

Motion and Forces

1. Motion:

   A. Recognize the speed of an object as change in position (distance) over time and acceleration as change in speed over time.

2. Common forces and their characteristics:

   A. Describe common mechanical forces (e.g., gravitational, normal, friction, elastic, buoyant); recognize and describe weight as a force due to gravity; differentiate between contact and non-contact forces (e.g., friction, gravity).

   B. Recognize that forces have strength and direction; recognize that for every action force there is an equal and opposite reaction force; recognize and describe the difference in the force of gravity on an object when it is located on different planets (or moons).

3. Effects of forces:

   A. Describe the functioning of simple machines (e.g., levers, inclined planes, pulleys, gears).

   B. Explain floating and sinking in terms of density differences and the effect of buoyant force.

   C. Describe pressure in terms of force and area; describe effects related to pressure (e.g., water pressure increasing with depth, a balloon expanding when inflated).

   D. Predict qualitative one-dimensional changes in motion (speed and direction) of an object based on the forces acting on it; recognize and describe how the force of friction affects motion (e.g., the contact area between surfaces can increase friction and impede motion).

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 2019 Science Framework identifies the following topic areas that are universally considered to be important for students at the eighth grade to understand as they learn about the planet on which they live and its place in the universe:

- 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, including Earth's structural layers, and the atmosphere. Students also should have a conceptual understanding of processes, cycles, and patterns, including geological processes that have occurred over Earth's history, the water cycle, and patterns of weather and climate. Students should demonstrate knowledge of Earth's resources and their use and conservation, and relate this knowledge to practical solutions to resource management issues. At this level, the study of Earth and the Solar System includes understanding how observable phenomena relate to the movements of Earth and the Moon, and describing the features of Earth, the Moon, and other planets.

Earth's Structure and Physical Features

1. Earth's structure and physical characteristics:

   A. Describe the structure of the Earth (i.e., crust, mantle, and core) and the physical characteristics of these distinct parts.

B. Describe the distribution of water on Earth in terms of its physical state (i.e., ice, water, and water vapor), and fresh versus salt water.

2. Components of Earth's atmosphere and atmospheric conditions:

A. Recognize that Earth's atmosphere is a mixture of gases; identify the relative abundance of its main components (i.e., nitrogen, oxygen, water vapor, and carbon dioxide), relate these components to everyday processes.

B. Relate changes in atmospheric conditions (i.e., temperature and pressure) to changes in altitude.

Earth's Processes, Cycles, and History

1. Geological processes:

A. Describe the general processes involved in the rock cycle (e.g., the cooling of lava, heat and pressure transforming sediment into rock, weathering, erosion).

B. Identify or describe changes to Earth's surface (e.g., mountain building), resulting from major geological events (e.g., glaciation, the movement of tectonic plates and subsequent earthquakes and volcanic eruptions).

C. Explain the formation of fossils and fossil fuels; use evidence from the fossil record to explain how the environment has changed over long periods of time.

2. Earth's water cycle:

A. Describe the processes in Earth's water cycle (i.e., evaporation, condensation, transportation, 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 (i.e., day-to-day variations in temperature, humidity, precipitation in the form of rain or snow, clouds, and wind) and climate (i.e., long-term typical weather patterns in a geographic area).

B. Interpret data or maps of weather patterns to identify climate types.

C. Relate the climate and seasonal variations in weather patterns to global and local factors (e.g., latitude, altitude, geography).

D. Identify or describe evidence for climate changes (e.g., changes that occur during ice ages, changes that are related to global warming).

Earth's Resources, Their Use and Conservation

1. Managing Earth's resources:
   - A. Provide examples of Earth's renewable and nonrenewable resources.
   - B. Discuss advantages and disadvantages of different energy sources (e.g., sunlight, wind, flowing water, geothermal, oil, coal, gas, nuclear).
   - C. Describe methods of conservation of Earth's resources and methods of waste management (e.g., recycling).
2. Land and water use:
   - A. Explain how common methods of land use (e.g., farming, logging, mining) can affect land and water resources.
   - B. Explain the importance of water conservation, and describe methods for ensuring that fresh water is available for human activities (e.g., desalination, purification).

Earth in the Solar System and the Universe

1. Observable phenomena on Earth resulting from movements of Earth and the Moon:
   - A. Describe the effects of the Earth's annual revolution around the Sun, given the tilt of its axis (e.g., different seasons, different constellations visible at different times of the year).
   - B. Recognize that tides are caused by the gravitational pull of the Moon, and relate phases of the Moon and eclipses to the relative positions of Earth, the Moon, and the Sun.
2. The Sun, stars, Earth, Moon, and planets:
   - A. Recognize that the Sun is a star and provides light and heat to each member of the Solar System; explain that the Sun and other stars produce their own light, but that other members of the Solar System are visible because of light reflected from the Sun.
   - B. Compare and contrast certain physical features of Earth with those of the Moon and other planets (e.g., presence and composition of an atmosphere, average surface temperature, presence of water, mass, gravity, distance from the Sun, period of revolution and rotation, ability to support life); recognize that the force of gravity keeps planets and moons in their orbits.

Science Cognitive Domains—Fourth and Eighth Grades

The cognitive dimension is divided into three domains that describe the thinking processes students are expected to engage in when encountering the science items developed for TIMSS 2019. The first domain, knowing, addresses the student's ability to recall, recognize, describe, and provide examples of facts, concepts, and procedures that are necessary for a solid foundation in science. The second domain, applying, focuses on using this knowledge to compare, contrast, and classify groups of objects or materials; relating knowledge of a science concept to a specific context; generating explanations; and solving 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 compared to the eighth grade, while the percentage of items that ask students to engage in reasoning is higher at the eighth grade compared to the fourth grade. While there is some hierarchy in the thinking processes across the three cognitive domains (from knowing to applying to reasoning), each cognitive domain contains items representing a full range of difficulty. Exhibit 2.4 shows the target percentages in terms of assessment time for each of the three cognitive domains at the fourth and eighth grades.

Exhibit 2.4: Target Percentages of the TIMSS 2019 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 includes knowing, applying, and reasoning items, as do 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 processes based on characteristics 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 2019

Scientists engage in scientific inquiry by following key science practices that enable them to investigate 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 2019:

1. **Asking questions based on observations**—Scientific inquiry includes observations of phenomena in the natural world. These observations, when considered together with theory, 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 relate their theories to properties 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, together with their theories 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 are 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. Some items in the TIMSS 2019 science assessment at both the fourth and eighth grades 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.

References

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CHAPTER 3

TIMSS 2019 Context Questionnaire Framework

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CHAPTER 3

TIMSS 2019 Context Questionnaire Framework

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At both the fourth and eighth grades, students participating in TIMSS complete questionnaires about their experiences, instruction, and attitudes toward learning mathematics and science. Their teachers and school principals complete questionnaires to provide data about school and classroom resources and approaches, and parents of fourth graders fill out a questionnaire about students' home contexts for learning. To better understand national contexts and policies, representatives from each participating country complete a curriculum questionnaire and contribute a chapter to the *TIMSS 2019 Encyclopedia*. Students taking TIMSS using a computer or tablet also fill out a short questionnaire about their experiences with computers and the Internet.

The TIMSS questionnaires have undergone a process of evolution and development since TIMSS was first administered in 1995, a process that continually sought to improve the quality and relevance of the data while keeping the response burden on principals, teachers, students, and parents to a minimum. In each four year assessment cycle, the questionnaire development team at the TIMSS & PIRLS International Study Center worked with the TIMSS Questionnaire Item Review Committee (QIRC) to review the questionnaires and suggest ways to update them—including adding new topics, refining individual questions, and deleting questions or topics that are no longer useful.

The TIMSS 2019 Context Questionnaire Framework describes those aspects of the learning context to be addressed by the TIMSS 2019 questionnaires, together with a rationale for why they should be included and research literature references as appropriate.

As a study of trends in student achievement and mathematics, TIMSS' first priority in characterizing the educational context is to gather data on policy relevant and malleable attributes of the home and school that can help interpret achievement changes from assessment to assessment. Where possible, such contextual data are summarized as context questionnaire scales that are used to measure changes from one assessment to the next. Relating changes in student achievement to changes in educational policies or practice can be a powerful source of evidence that the policy or practice is beneficial for student learning.

For example, TIMSS 2015 reported differences from TIMSS 2011 on a number of background scales such as the *Early Literacy and Numeracy Activities* scale and the *Students Like Learning Mathematics* scale. TIMSS 2019 plans to improve and expand trend measurement using these and other scales.

The TIMSS 2019 Context Questionnaires have the dual purpose of linking to the past and building a bridge to the future. The world is changing in important ways, and so are educational policies and practices around the world. It is important for the TIMSS 2019 Context Questionnaires to reflect these changes. This will be managed by updating aspects of existing scales to reflect new and improved understandings of the constructs being measured, and also by including new scales about important aspects of educational effectiveness.

The framework also includes other topics that are important to TIMSS participating countries and education researchers but have not been shown to be related to achievement on the TIMSS assessment. These topics are generally considered to be important aspects of the education systems and beneficial for student learning, and TIMSS plays a key role in collecting data on these topics in the international context. For example, through the curriculum questionnaire and TIMSS Encyclopedia, TIMSS plays an important role in documenting international trends in curricular policy and other educational policies. However, many country level policies do not show a direct relationship with TIMSS achievement.

The remainder of this chapter details the topics to be covered in the TIMSS 2019 context questionnaires. The chapter is structured to focus on five broad areas:

- Community and national policies
- Home contexts
- School contexts
- Classroom contexts
- Student attitudes toward learning

Community and National Policies

Countries, regions, and communities make key educational policy decisions about the curriculum and how it is best implemented. Primarily through the TIMSS Encyclopedia and curriculum questionnaires, TIMSS 2019 will cover five broad national and community policies:

- Intended mathematics and science curriculum
- Language(s) of instruction
- Student flow
- Teacher education
- Principal certification

Intended Mathematics and Science Curriculum

Since 1995, TIMSS has collected extensive data on the content of the intended curriculum. Whether formulated at the national, community, or school level, curricular documents define and communicate the curriculum, providing expectations for students in terms of the knowledge, skills, and attitudes to be developed or acquired through their formal mathematics and science education.

Internationally, mathematics and science curricula differ across countries and are constantly evolving. In mathematics, countries differ in the degree of emphasis they place on acquiring basic skills, memorizing rules, procedures, or facts, understanding mathematical concepts, applying mathematics to "real life" situations, communicating or reasoning mathematically, and problem solving in everyday situations. In science, countries vary in the extent that they focus on acquiring basic science facts, understanding and applying science concepts, formulating hypotheses, designing and conducting investigations to test hypotheses, using inquiry-based learning, and communicating scientific explanations. Differences in the structure of the science curriculum can result in different experiences for students in different countries. By the eighth grade, some countries teach science as separate subjects (biology, chemistry, physics, and earth science), and others teach it as one integrated subject.

Continuing previous practices, countries will provide summaries of their fourth and eighth grade mathematics and science curricula in the *TIMSS 2019 Encyclopedia* and answer questions about their curricula in the curriculum questionnaire. Collecting data on curricular content over time can provide insights into the evolution of national curricula. For example, the *TIMSS 2015 Encyclopedia* (Mullis, Martin, Goh, & Cotter, 2016) found that countries are increasingly incorporating problem solving into their mathematics curricula and are incorporating inquiry and investigative skills into the science curricula. To an increasing extent, curricula are also emphasizing the integration of technology into mathematics and science learning.

Language(s) of Instruction

A multilingual population can increase the challenge of implementing the mathematics and science curricula, and for these reasons the *TIMSS 2019 Encyclopedia* will contain information about languages of instruction. Some countries have one commonly spoken language, while others are historically multilingual. Immigration also can increase the language diversity in countries. Most of the TIMSS participating countries deliver instruction in multiple languages.

Student Flow

TIMSS 2019 will continue collecting data on student flow through the education system through the curriculum questionnaire. Student flow decisions made at the national and community levels include decisions on access to preprimary education, age of entry into formal education, and policies on grade retention and educational tracking.

- **Preprimary Education**—Even before they begin formal primary school, children receive considerable exposure to literacy, numeracy, and science as part of their preprimary educational experience (e.g., preschool, Kindergarten). Preprimary education is an area of investment for many countries. Research findings indicate that attendance at preprimary programs can have a positive effect on academic outcomes (Duncan & Magnusson, 2013). As described in the *TIMSS 2015 Encyclopedia* (Mullis, Martin, Goh, & Cotter, 2016), almost all countries participating in TIMSS 2015 provided universal preprimary education for children age 3 or older, and a number of countries also sponsored universal programs for children younger than 3 years old.
- **Age of Entry**—Policies about the age of entry into formal education (first year of primary school, ISCED Level 1) are important for understanding achievement as well as the variation in students' ages across countries at the fourth grade (Martin, Mullis, & Foy, 2011). Typically, across the TIMSS countries, students enter primary school at ages 5 to 7.
- **Grade Retention**—Because TIMSS is a grade-based study, the degree of grade retention can be an important factor to consider when evaluating achievement results. Research has shown that grade retention does not have a positive relationship with student achievement or the emotional well-being of the student and is overall inefficient (García-Pérez, Hidalgo-Hidalgo, & Robles-Zurita, 2014; Hattie, 2009). Many TIMSS countries practice automatic promotion, especially in the primary grades (Mullis, Martin, Goh, & Cotter, 2016).
- **Tracking**—Some education systems address differential student abilities and interests by assigning students to different schools that provide academic or vocational routes. A breadth of literature has suggested that tracking students into different schools or routes early in the educational process can exacerbate differences in student achievement (Hanushek & Wößmann, 2006; Marks, 2005; Parker, Jerrim, Schoon, & Marsh, 2016; Schütz, Ursprung, & Wößmann, 2008; Van de Werfhorst & Mijs, 2010). Given that educational tracking can begin as early as middle school, the timing and extent of educational tracking is especially important for interpreting the eighth grade results.

Teacher Education

In every country, teachers are the primary implementers of the curriculum, so teacher education policies and practices are a major interest. TIMSS 2019 will collect information about teacher preparation, certification, and professional development. As described in the *TIMSS 2015 Encyclopedia*, many countries have increased the educational requirements for teachers, particularly for primary school teachers as well as secondary school science teachers. As of 2015, almost all TIMSS countries called for fourth and eighth grade teachers to have a four year degree from a university, and the percentage of teachers at both grade levels who had a bachelor's degree increased from 2007. A number of countries have also strengthened the requirements for entry to teacher education programs, with some requiring that prospective teachers achieve a minimum grade point average or pass an examination.

Principal Certification

Given the central role principals play in managing teachers, students, and school resources, TIMSS will continue collecting data on national principal certification policies. To encourage the development of strong leadership skills, some countries have specific education and training requirements for principals, such as the completion of certification programs in school leadership or specialized principal training programs.

Home Contexts

Parents or guardians and the general home environment are very influential on children's upbringing and their success in school. To better understand the effects of the home context on student achievement in mathematics and science, TIMSS 2019 will collect data through the home questionnaire given to the parents or caregivers of fourth grade students, supplemented by the student questionnaire at the fourth and eighth grades. This will include the following topics:

- Home resources for learning
- Language(s) spoken in the home
- Early literacy and numeracy activities
- Preprimary education

Home Resources for Learning

In education research, the aspects of home background that show the most consistent association with student achievement tend to be those that measure the socioeconomic status of the parents or caregivers (Dahl & Lochner, 2012; Davis-Kean, 2005; Martin, Foy, Mullis, & O'Dwyer, 2013; Sirin, 2005; Willms, 2006). Socioeconomic status is often indicated through proxy variables such as parental level of education, income, occupational class, and the number of books in the home. TIMSS has developed two scales that expand upon the classic conception of socioeconomic status to include home resources with the potential to facilitate student learning (e.g., an Internet connection): 1) the fourth grade TIMSS *Home Resources for Learning* scale based primarily on data from the home questionnaire, and 2) the eighth grade *Home Educational Resources* scale based on the data from the eighth grade student questionnaire. These two scales have shown a strong positive relationship with students' mathematics and science achievement in previous TIMSS cycles, and also will be included in TIMSS 2019.

Language(s) Spoken in the Home

TIMSS 2019 will collect information from students and parents on the language the child speaks in the home. Internationally, there are many reasons why some children speak a different language in the home than they do in the school. Some countries have numerous national languages and in these countries it is not uncommon for students to speak one language at home and another at school. Speaking another language in the home can also be common among immigrant families. In addition, some parents prioritize multilingualism and make great efforts to ensure their child is exposed to more than one language in the home.

Early Literacy and Numeracy Activities

Children's first teachers are their parents/guardians. The TIMSS 2019 home questionnaire will ask the parents/guardians of fourth grade students to provide information on the frequency that they engaged their child in early literacy and numeracy activities before beginning primary school. The questionnaire also will ask parents to report how well their child could do certain literacy and numeracy tasks upon entering primary school.

Considerable research, including results from TIMSS and PIRLS, has documented the importance of early childhood learning activities and their relationship with student achievement and other educational outcomes (Anders et al., 2012; Gustafsson, Hansen, & Rosén, 2013; Hart & Risley, 2003; Hooper, 2017; Melhuish et al., 2008; Sarama & Clements, 2009; Sénéchal & LeFevre, 2002; Skwarchuk, Sowinski, & LeFevre, 2014).

Engaging children in early numeracy activities can stimulate their interest in mathematics and enhance the development of their numeracy skills (Anders et al., 2012; Claessens & Engel, 2013; Melhuish et al., 2008; Sarama & Clements, 2009). These activities include playing with blocks or construction toys, saying counting rhymes or singing counting songs, playing games involving shapes, and playing other types of games that involve quantitative reasoning. Students who have early numeracy skills when entering school often have higher achievement in primary school (Duncan et al., 2007; Princiotta, Flanagan, & Hausken, 2006).

As recently demonstrated by analyses of TIMSS and PIRLS 2011 data (Gustafsson et al., 2013; Punter, Glas, & Meelissen, 2016), both early numeracy and literacy activities are related to a child's fourth grade achievement in mathematics, science, and reading. The association between early literacy activities and mathematics achievement could be linked to the fact that completing numeracy tasks often requires reading skills (Mullis, Martin, & Foy, 2013).

Preprimary Education

TIMSS 2019 will collect data from parents on the duration of their child's preprimary school attendance—consistently identifying a positive relationship between duration of preprimary attendance and student achievement. Much research has detailed the importance of preprimary education (e.g., preschool, Kindergarten, early childhood education programs) on fostering higher academic outcomes (Duncan & Magnusson, 2013). It is argued that high quality preprimary education and other early childhood interventions are especially beneficial for disadvantaged students because they can play an important role in breaking the generationally repetitive cycle of poverty and low achievement (Duncan & Sojourner, 2013; Heckman & Masterov, 2007).

School Contexts

A school's environment and organization can be an important determinant of effectiveness in reaching curricular goals. Accepting that an effective school is not simply a collection of discrete attributes, but rather a well managed, integrated system where each action or policy directly affects all other parts, the TIMSS 2019 school questionnaire will focus on a set of well researched school quality indicators:

- School characteristics and demographics
- Instruction affected by mathematics and science resource shortages
- School emphasis on academic success
- Parents' perception of their child's school
- Safe and orderly schools
- Student bullying
- Sense of school belonging

School Characteristics and Demographics

To provide key contextual information about schools, the TIMSS 2019 school questionnaire will collect data from principals on a number of school characteristics including school size, school location, and school composition by economic status and language use. In addition, principals are asked about the proportion of the students who enter school with various early literacy and numeracy skills.

TIMSS results have typically included data on school composition by economic status, measured by principals' estimates of the percentage of students from advantaged and disadvantaged backgrounds. Since the Coleman report (Coleman et al., 1966), there has been great emphasis on how the socioeconomic composition of the student body is associated with individual student achievement (Martin, Foy, Mullis, & O'Dwyer, 2013; Rumberger & Palardy, 2005; Sirin, 2005). There is evidence that students from disadvantaged backgrounds may have higher achievement if they attend schools where the majority of students are from advantaged backgrounds. Some have attributed this association to peer effects—observing a strong relationship between students and their classmates (Sacerdote, 2011). The higher achievement for students in socioeconomically advantaged schools may also be partially explained by such schools having better facilities, instructional materials, and teachers. For example, in some countries, schools with high proportions of disadvantaged students have difficulty attracting highly qualified teachers (Akiba, LeTendre, & Scribner, 2007; Clotfelter, Ladd, & Vigdor, 2010).

Instruction Affected by Mathematics or Science Resource Shortages

Adequate working conditions and facilities, as well as sufficient instructional resources, are important for maintaining a favorable learning environment in schools (Cohen, McCabe, Michelli, & Pickeral, 2009). Although "adequacy" in terms of resources can be relative, the extent and quality of school resources have been shown to be critical for quality instruction (Glewwe, Hanushek, Humpage, & Ravina, 2011; Hanushek, 1997; Hanushek & Wößmann, 2017; Lee & Barro, 2001; Lee & Zuze, 2011). Results from TIMSS international reports indicate that students in schools that are well resourced generally have higher achievement than those in schools where shortages of resources affect the capacity to implement the curriculum.

Through the *Instruction Affected by Mathematics Resource Shortages* scale and the *Instruction Affected by Science Resource Shortages* scale, both based on principal reports, TIMSS 2019 will measure how general and subject-specific resource shortages affect curriculum implementation. General resources include teaching materials, supplies, school buildings and grounds, heating/cooling and lighting systems, classroom space, technology-based equipment such as electronic whiteboards, computers and tablets, videos, and Internet access. Subject-specific resources for mathematics and science may include subject-specific software/applications, calculators, laboratory equipment, and instructional materials. In addition, TIMSS typically collects information on whether the school has a library or media center and a science laboratory, as well as the number of computers in the school.

School Emphasis on Academic Success

TIMSS 2019 will ask teachers and principals about the extent to which their school emphasizes academic success. Overall, a positive school atmosphere with high expectations for academic excellence can contribute to the success of a school. Following the TIMSS and PIRLS 2011 school effectiveness study (Martin, Foy, Mullis, & O'Dwyer, 2013), TIMSS 2015 results showed a positive association between academic achievement and a school's emphasis on academic success. Aligning with the literature on academic optimism (Hoy, Tarter, & Hoy, 2006; McGuigan & Hoy, 2006; Wu, Hoy, & Tarter, 2013), indicators for the TIMSS measure of school emphasis on academic success include school administrators' and teachers' expectations for successful curriculum implementation and student achievement, parental support for student achievement, and the students' desire to achieve.

Schools can also vary on how much they specifically emphasize preparing students in science, technology, engineering, and mathematics (STEM) subjects. The results from TIMSS Advanced 2015, which assessed students at the end of secondary school, showed a relationship between the degree a school supports advanced mathematics and physics education and achievement. Indicators of school STEM support include school initiatives promoting student interest in the subjects, such as after school activities, as well as STEM-specific professional development programs for teachers.

Parents' Perceptions of Their Child's School

TIMSS 2019 will collect information on what parents think about their child's school, by asking parents to indicate their level of agreement with statements that evaluate the school academically as well as school safety and the extent that schools communicate with and involve parents in their child's education. TIMSS 2015 results show that most parents tended to be satisfied with the school their child attended, which is consistent with results from other educational surveys (Barrows, Peterson, & West, 2017; Stacer & Perrucci, 2013).

Safe and Orderly Schools

TIMSS 2019 will ask teachers and principals to report on school safety and discipline. TIMSS reports have consistently shown a positive relationship between student achievement and teachers' and principals' reports that the school is safe and orderly, and school effectiveness research analyzing TIMSS/PIRLS 2011 data showed that school safety was an important predictor of student achievement in many countries (Martin, Foy, Mullis, & O'Dwyer, 2013). Respect for individual students and teachers, a safe and orderly environment, and constructive interactions among administrators, teachers, parents, and students all contribute to a positive school climate and are associated with higher student achievement (Cohen et al., 2009; Greenberg, Skidmore, & Rhodes, 2004; Konishi, Hymel, Zumbo, & Li, 2010). The sense of security that comes from having few behavioral problems and little or no concern about student or teacher safety at school promotes a stable learning environment. A general lack of discipline, especially if students and teachers are afraid for their safety, does not facilitate learning and is related to lower academic achievement (Milam, Furr-Holden, & Leaf, 2010; Stanco, 2012). Schools where there are clear rules and more fairness tend to have atmospheres of greater discipline and safety (Cohen et al., 2009; Gottfredson, Gottfredson, Payne, & Gottfredson, 2005).

Student Bullying

TIMSS 2019 will ask students to report the frequency with which they are bullied. Previous TIMSS reports have shown that bullied students tend to have lower mathematics and science achievement, aligning with findings of other research (Glew, Fan, Katon, & Rivara, 2008; Konishi et al., 2010; Rothon, Head, Klineberg, & Stansfeld, 2011; Rutkowski, Rutkowski, & Engel, 2013). Bullying is repeated aggressive behavior that is intended to harm students who are physically or psychologically less strong, and takes a variety of forms ranging from name calling to inflicting mental and physical harm. Bullying causes distress to victims, leads to low self-esteem, and makes victims feel like they do not belong (Glew et al., 2008). With the prevalence of the Internet, cyberbullying unfortunately appears to be common among students; and, like other bullying, cyberbullying, is associated with low self-esteem, distress, and poor achievement (Mishna, Cook, Gadalla, Daciuk, & Solomon, 2010; Tokunaga, 2010).

Sense of School Belonging

TIMSS 2019 will collect data from students on their sense of school belonging. TIMSS 2015 results showed an association between school belonging and academic achievement, corroborating other research on the subject (Cohen et al., 2009; McMahon, Wernsman, & Rose, 2009). In addition, students' sense of belonging to their school, also referred to as school connectedness, contributes to their general well-being (Joyce & Early, 2014; McLellan & Steward, 2015; Renshaw, Long, & Cook, 2015). Students with a strong sense of belonging feel safe at school, enjoy school, and have good relationships with teachers and classmates.

Classroom Contexts

Because most teaching and learning in school takes place in the classroom, successful learning is likely to be influenced by the classroom environment and instructional activities. Through the teacher and student questionnaires, TIMSS 2019 will focus on the following factors and practices that are influential to teaching and learning:

- Teacher preparation and experience
- TIMSS mathematics and science topics taught
- Instructional time
- Instructional practices and strategies
- Instructional clarity
- Supportive classroom climate
- Use of technology in instruction
- Challenges faced by teachers

Teacher Preparation and Experience

Through the teacher questionnaire, TIMSS 2019 will collect extensive data on teacher preparation, professional development, and teaching experience. Preparation is critical for effective teaching (Darling-Hammond, 2000; Hill, Rowan, & Ball, 2005), and prospective teachers need coursework to gain knowledge in the subjects that they will teach, to understand about how students learn, and to learn about effective pedagogy in teaching mathematics and science.

Professional development through seminars, workshops, and conferences can help teachers increase their effectiveness and broaden their knowledge (Blank & de las Alas, 2009; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Professional development is especially important for exposing teachers to recent developments such as curricular changes or new technology for classroom instruction. The *TIMSS 2015 Encyclopedia* shows that many countries are increasing efforts to provide teachers with professional development opportunities.

In addition to education and training, teaching experience is essential, and the first years of teaching are especially important for teacher development (Harris & Sass, 2011; Leigh, 2010). Research also has found that teachers continue to develop pedagogical skills after five years of experience, and that this development can positively affect student achievement (Harris & Sass, 2011).

TIMSS Mathematics and Science Topics Taught

Since the first cycle of TIMSS in 1995, TIMSS has collected extensive data on the implemented curriculum—documenting the extent to which the mathematics and science topics in the TIMSS frameworks are covered in the classroom. TIMSS 2019 will collect this information by asking the mathematics and science teachers of the participating students to indicate whether each of the topics assessed has been covered in class in current or previous years.

Instructional Time

Key to curriculum implementation is the amount of instructional time teachers have to teach the mathematics and science curricula. For this reason, TIMSS 2019 will collect information from teachers and principals on instructional time. TIMSS results show that there is variation among countries in the intended instructional time prescribed by the curriculum and in the actual time of implementation in the classroom. Research has found instructional time to be related to student achievement (Hanushek & Wößmann, 2017), although such relationships may depend on how efficiently and effectively instructional time is used (Mullis, Martin, & Loveless, 2016). For example, teachers who are strong classroom managers may be more efficient, as they can focus the instructional time on teaching the curricular content.

Homework is one way teachers can extend instruction and evaluate student learning. The amount of homework assigned varies both within and across countries, with homework not assigned at all to fourth grade students in some countries. TIMSS 2019 will collect data on homework assignments, including how homework is used, through the teacher questionnaire at the fourth and eighth grades and the student questionnaire at the eighth grade. Although there are differences across countries, most eighth grade mathematics and science teachers assign homework, discuss the homework in class, and provide feedback to students. Students' reports on time spent completing homework do not show a clear relationship with TIMSS achievement—perhaps because struggling students take a longer amount of time to complete their homework. Homework assignments may also be redundant with classroom instruction, not reinforcing or extending the instruction.

Instructional Practices and Strategies

Since 1995, the TIMSS teacher questionnaires have collected important information on the frequency with which teachers implement various instructional practices and strategies. For TIMSS 2019, mathematics-specific practices will include the frequency that students work on problems on their own, the frequency that they explain their answers in class, and the frequency with which they are asked to decide their own problem solving strategies. Science practices will focus on the frequency that teachers emphasize science investigation, with items focusing on student exposure to experiments and investigations within their science lessons.

Instructional Clarity

The TIMSS 2019 student and teacher questionnaires will include a renewed focus on instructional quality, including updating scales measuring instructional clarity (Nilsen, Gustafsson, & Blömeke, 2016). As described by Ferguson (2012), an important quality of an effective teacher is the ability to provide clear instruction—explaining the content clearly and gauging student understanding of the topic. For challenging topics, it is often necessary for the teacher to employ a variety of pedagogical techniques and explanations to ensure student comprehension. Another way that teachers can increase clarity is by linking new concepts to things students already know and understand (McLaughlin et al., 2005).

The TIMSS 2019 Instructional Clarity scales benefit from two previous efforts. Five of the 10 items in each of the TIMSS 2015 *Students' Views on Engaging Teaching* scales at fourth and eighth grades measured instructional clarity. The scales showed positive associations between instructional clarity and student achievement in many participating countries, especially at the eighth grade. A number of countries also included a national extension in the fourth grade student questionnaire, and the results showed higher achievement for students reporting greater instructional clarity by their teachers (Bergem, Nilsen, & Scherer, 2016).

Supportive Classroom Climate

TIMSS 2019 also plans for the student and teacher questionnaires to contain new Supportive Classroom Climate scales. The TIMSS 2015 national extension (Bergem et al., 2016; Wendt, Bos, Selter, Köller, Schwippert, & Kasper, 2016) included a scale measuring supportive climate, which was based on the work of Baumert et al. (2010) and Klieme, Pauli, & Reusser (2009). The TIMSS 2015 national extension found a positive relationship between a supportive climate and student achievement. A supportive environment has also been found to increase student motivation and participation (Cornelius-White, 2007; Fauth, Decristan, Rieser, Klieme, & Büttner, 2014; Marzano, Marzano, & Pickering, 2003).

Teachers can create a supportive environment by providing positive feedback, listening and responding to students' questions, and being empathetic to students' needs (Reeve, 2002). Indicators of a supportive climate include the frequency with which the teacher helps students learn and the teacher showing interest in student learning, as well as the frequency that the teacher asks students to express their opinions.

Use of Technology in Instruction

Educational systems throughout the world are investing resources to ensure that classrooms are well equipped with instructional technology, and countries are also using technology more in assessment. TIMSS 2019 will document how mathematics and science teachers use instructional technology in the classroom. For mathematics, data will be collected on teachers' reports of how often they have students do mathematics activities on computers, such as solving mathematics problems or exploring mathematics concepts. In science, data also will be collected on science specific activities such as whether teachers use technology to conduct or simulate experiments and investigations. In addition, students provide data on their use of technology for learning at home and in school.

With TIMSS 2019 being administered in many countries on personal computers and tablets, TIMSS 2019 also will collect data on students' experiences taking tests on digital devices. It is expected that some students will have had extensive experience taking both formative and summative assessments online, and other students will have had less experience with digital assessment.

Challenges Faced by Teachers

Mathematics and science teachers face a number of challenges in fulfilling all of the obligations of their position in the school. The TIMSS 2019 teacher questionnaires will ask about having too many students in the class, being burdened with administrative duties, and not having enough time to prepare lessons. Teaching can also be more difficult when students have frequent absences from school or do not have the prerequisite foundation of content knowledge to learn the new mathematics or science content. It can also be difficult to teach students who come to school tired or hungry.

Student Attitudes Toward Learning

Improving students' attitudes toward learning is a major curricular goal for many countries (Mullis, Martin, Goh, & Cotter, 2016), and an abundance of research has documented the relationship between student achievement and student attitudes. IEA has collected extensive information about student attitudes toward mathematics and science since its initial studies in these curriculum areas.

Student Attitudes Toward Mathematics and Science

As described by Mullis, Martin, and Hooper (2017), TIMSS has been measuring student attitudes toward mathematics and science achievement since 1995. TIMSS 2019 will continue measuring students' attitudes through a number of scales, including *Students Like Learning Mathematics*, *Students Value Mathematics*, and *Students Confident in Mathematics*, with equivalent scales in science measuring similar constructs.

The *Students Like Learning Mathematics* and *Students Like Learning Science* scales measure a student's intrinsic motivation to learn the subjects. Intrinsic motivation is the "energizer of behavior" (Deci & Ryan, 1985, p. 32). Students who are intrinsically motivated to learn mathematics or science find the subject to be interesting and enjoyable. TIMSS data have shown a strong relationship between these scales and student achievement.

TIMSS measures extrinsic motivation through the eighth grade *Students Value Mathematics* and *Students Value Science* scales. Extrinsic motivation refers to the drive that comes from external rewards like praise, career success, money, and other incentives. Research has consistently shown that intrinsic motivation is more closely related to achievement than extrinsic motivation (Becker, McElvany, & Kortenbruck, 2010; Vansteenkiste, Timmermans, Lens, Soenens, & Van den Broeck, 2008). Nevertheless, TIMSS results have consistently shown a strong relationship between students valuing the subject and their achievement.

TIMSS also measures subject-specific self-concept through the *Students Confident in Mathematics* scales and *Students Confident in Science* scales, and the results from six previous TIMSS cycles have shown a strong relationship between students' academic self-concepts and their achievement. Students tend to have distinct views of their ability in different subjects, and their self-appraisal is often based on their past experiences and how they see themselves compared with their peers (Marsh & Craven, 2006).

Student Confidence Using Technology

One of the biggest changes in education since the inception of TIMSS has been schools' increasing reliance on technology. As reported in the *TIMSS 2015 Encyclopedia*, most TIMSS countries are working toward integrating technology into instruction across the curriculum to help make teaching and learning more engaging and efficient. Consistent with increased attention across the TIMSS 2019 questionnaires on the areas of technology availability and use, TIMSS 2019 will assess students' degree of confidence in using digital devices. The students participating in eTIMSS 2019 will be asked additional questions specific to the eTIMSS experience.

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IEA TIMSS 2019

CHAPTER 4

TIMSS 2019 Assessment Design

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CHAPTER 4

TIMSS 2019 Assessment Design

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TIMSS is designed to provide countries with information about their students' mathematics and science achievement that can be used to inform evidence-based decisions for improving educational policy and practice. At the heart of TIMSS is a wide ranging student assessment of mathematics and science achievement conducted at four year intervals at fourth and eighth grades, together with questionnaires for parents, students, teachers, school principals, and curriculum experts that gather information about the social and educational contexts for learning.

Central to TIMSS' mission is the measurement of student achievement in mathematics and science in a way that does justice to the breadth and richness of these subjects as they are taught in the participating countries, and that monitors countries' improvements or declines by tracking trends in student performance from one assessment cycle to the next. This requires an assessment that is wide ranging in its coverage of mathematics and science and innovative in its measurement approach.

Conducted every four years since 1995, with each assessment linked to the one that preceded it, TIMSS provides regular and timely data for educators and policymakers on trends in students' mathematics and science achievement. As an additional advantage, administering TIMSS at the fourth and eighth grades every four years provides the opportunity to monitor achievement changes within a grade cohort, as the fourth grade students in one TIMSS cycle become the eighth grade students in the next cycle.

The seventh in the TIMSS series of assessments, TIMSS 2019 continues the TIMSS tradition of innovation by beginning the transition to the eTIMSS digital format. For the first time, about half the countries will transition to administering the assessment via computer, while the rest will administer TIMSS in a paper and pencil format as in previous assessments.

Student Populations Assessed

TIMSS assesses the mathematics and science achievement of students in their fourth and eighth years of formal schooling. Participating countries may choose to assess one or both populations, according to their policy priorities and resource availability. Because in TIMSS the number of years of formal schooling (four or eight) is the basis for comparison among participating countries, the TIMSS assessment is targeted at the grade levels that correspond to these. The TIMSS target populations are defined as follows:

- At the fourth grade, the TIMSS target grade should be the grade that represents four years of schooling, counting from the first year of ISCED Level 1.
- At the eighth grade, the TIMSS target grade should be the grade that represents eight years of schooling, counting from the first year of ISCED Level 1.

ISCED is the International Standard Classification of Education developed by the UNESCO Institute for Statistics and provides an international standard for describing levels of schooling across countries (UNESCO, 2012). The ISCED system describes the full range of schooling, from preprimary (Level 0) to doctoral study (Level 8). ISCED Level 1 corresponds to primary education or the first stage of basic education. Four years after the beginning of Level 1 is the fourth year of formal schooling and is the target grade for the fourth grade TIMSS assessment. This also is the fourth grade in most countries. Similarly, eight years after the first year of ISCED Level 1 is the target grade for eighth grade TIMSS, and is the eighth grade in most countries. However, given the cognitive demands of the assessments, TIMSS wants to avoid assessing very young students. Thus, TIMSS recommends that countries assess the next higher grade (i.e., fifth grade for fourth grade TIMSS, and ninth grade for eighth grade TIMSS) if, for fourth grade students, the average age at the time of testing would be less than 9.5 years, and, for eighth grade students, less than 13.5 years.

To represent the target population with an acceptable margin of error while keeping the assessment burden on schools and students to a minimum, each country selects a nationally representative probability sample of students at each grade. The basic TIMSS sample design consists of at least 150 schools and one or more intact classes per grade, for a student sample of approximately 4,000 students in each country.

Reporting Student Achievement

TIMSS 2019 provides a comprehensive picture of the mathematics and science achievement of fourth and eighth grade students in each participating country. This includes achievement in each of the content and cognitive domains (as defined in Chapters 1 and 2) as well as overall mathematics and science achievement. Consistent with the goal of comprehensive subject coverage, the complete TIMSS 2019 assessment consists of a large pool of mathematics and science questions (known as items) at each grade level. However, to keep the assessment burden on any one student to a minimum, each student is presented with only a sample of the items, as described in the next section. Following data collection, student responses to the items in each assessment are aggregated and converted to the TIMSS mathematics and science scale metrics at each grade level to provide an overall picture of the assessment results for each country.

One of the major strengths of TIMSS is its measurement of trends over time in mathematics and science achievement. The TIMSS achievement scales provide established metrics on which countries can compare students' progress in mathematics and science from assessment to assessment at the fourth and eighth grades. The TIMSS mathematics and science achievement scales were created with the first TIMSS assessment in 1995, separately for each subject and each grade. The scale units were established so that 100 points on the scale was equivalent to one standard deviation of the distribution of achievement across all of the countries that participated in TIMSS 1995, and the scale midpoint of 500 was located at the mean of this international achievement distribution. The TIMSS achievement scales were first used for reporting TIMSS results with TIMSS 1995, and all results from subsequent TIMSS assessments have been reported on the same scale metrics, making it possible to measure growth or decline in countries' achievement distributions from assessment to assessment.

Using items that were administered in both 1995 and 1999 assessments as a basis for linking the two sets of assessment results, the TIMSS 1999 data also were placed on the scales so that countries could gauge changes in students' mathematics and science achievement since 1995. This was done separately for mathematics and science and for fourth and eighth grades. Using similar procedures, the data from TIMSS 2003, TIMSS 2007, TIMSS 2011, and TIMSS 2015 were placed on the TIMSS scales, as will be the data from TIMSS 2019. This will enable TIMSS 2019 countries that have participated in TIMSS since its inception to have comparable achievement data from 1995, 1999, 2003, 2007, 2011, 2015, and 2019, and to plot changes in performance over this 24 year period.

As previously mentioned, in addition to the achievement scales for mathematics and science overall, TIMSS 2019 will construct scales for reporting relative student performance in each of the mathematics and science content and cognitive domains defined in the TIMSS 2019 Assessment Frameworks. More specifically, in mathematics at the fourth grade there will be three content scales, corresponding to the three content domains—number, measurement and geometry, and data display—and four at the eighth grade—number, algebra, geometry, and data and probability. In science, there also will be three content scales at fourth grade—life science, physical science, and Earth science—and four at the eighth grade—biology, chemistry, physics, and Earth science. The TIMSS 2019 Assessment Frameworks also specify three cognitive domains— knowing, applying, and reasoning—which span the mathematics and science content at both grades. Reporting scales will be constructed for each cognitive domain in mathematics and science at each grade level.

TIMSS 2019 Student Booklet Design

A major consequence of TIMSS' ambitious reporting goals is that many more questions are required for the assessment than can be answered by any one student in the amount of testing time available. Accordingly, TIMSS uses a matrix sampling approach that involves packaging the entire assessment pool of mathematics and science items at each grade level into a set of 14 student achievement booklets, with each student completing just one booklet. Each item appears in two booklets, providing a mechanism for linking together the student responses from the various booklets when data from all booklets are taken together. Booklets are distributed among students in participating classrooms according to assignments predetermined by the TIMSS within-school sampling software, so that the student samples completing each booklet in each country are approximately equivalent in terms of student ability.

After the assessment has been administered and the data collected and processed, TIMSS uses item response theory scaling methods to assemble a comprehensive picture of the achievement of the entire student population of a country from the combined responses of individual students to the booklets that they are assigned.[1] This approach reduces to manageable proportions what otherwise would be an impossible student burden, albeit at the cost of some complexity in booklet assembly, data collection, and data analysis.

To facilitate the process of creating the student achievement booklets, TIMSS groups the assessment items into a series of item blocks, with approximately 10 to 14 items in each block at the fourth grade and 12 to 18 at the eighth grade. As far as possible, within each block the distribution of items across content and cognitive domains matches the distribution across the item pool overall, as described in Chapters 1 and 2. Similar to the TIMSS 2015 assessment, TIMSS 2019 has a total of 28 blocks at each grade, 14 consisting of mathematics items and 14 consisting of science items. Student booklets are assembled from various combinations of these item blocks.

Following the 2015 assessment, eight of the 14 mathematics blocks and eight of the 14 science blocks at each grade were secured for use in 2019 as a basis for measuring trends. The remaining 12 blocks (six mathematics and six science) were available with permission from IEA for use in publications, research, and teaching, and had to be replaced by newly developed items for the TIMSS 2019 assessment. Accordingly, the 28 blocks in the TIMSS 2019 assessment comprise 16 blocks of trend items (eight mathematics and eight science) and 12 blocks of new items to be used for the first time in 2019.

As shown in Exhibit 4.1, the TIMSS 2019 mathematics blocks are labeled M01 through M14 and the science blocks S01 through S14. Mathematics and science blocks ending in odd numbers (01, 03, 05, etc.) contain the trend items from the 2015 assessment, as do blocks ending in 06. The blocks ending in even numbers (except 06) contain the items developed for use for the first time in TIMSS 2019.

1 See Foy and Yin (2016) for a description of the scaling of the TIMSS 2015 achievement data.

Exhibit 4.1: TIMSS 2019 Item Blocks—Fourth and Eighth Grades

Mathematics Blocks	Source of Items	Science Blocks	Source of Items
M01	Trend Block M13 from TIMSS 2015	S01	Trend Block S13 from TIMSS 2015
M02	New items for TIMSS 2019	S02	New items for TIMSS 2019
M03	Trend Block M08 from TIMSS 2015	S03	Trend Block S08 from TIMSS 2015
M04	New items for TIMSS 2019	S04	New items for TIMSS 2019
M05	Trend Block M09 from TIMSS 2015	S05	Trend Block S09 from TIMSS 2015
M06	Trend Block M10 from TIMSS 2015	S06	Trend Block S10 from TIMSS 2015
M07	Trend Block M11 from TIMSS 2015	S07	Trend Block S11 from TIMSS 2015
M08	New items for TIMSS 2019	S08	New items for TIMSS 2019
M09	Trend Block M04 from TIMSS 2015	S09	Trend Block S04 from TIMSS 2015
M10	New items for TIMSS 2019	S10	New items for TIMSS 2019
M11	Trend Block M12 from TIMSS 2015	S11	Trend Block S12 from TIMSS 2015
M12	New items for TIMSS 2019	S12	New items for TIMSS 2019
M13	Trend Block M14 from TIMSS 2015	S13	Trend Block S14 from TIMSS 2015
M14	New items for TIMSS 2019	S14	New items for TIMSS 2019

Fourth grade students are expected to spend, on average, 18 minutes on each item block, and eighth grade students, 22½ minutes. Consequently, the 28 blocks of fourth grade items are estimated to contain almost 8½ hours of testing time and the eighth grade blocks about 10½ hours. In previous TIMSS cycles, National Research Coordinators from participating countries agreed that the testing time for any one student should not be increased from previous assessments. Thus, as in the past, the assessment time for each student booklet must fit into 72 minutes for the fourth grade and 90 minutes for the eighth grade. An additional 30 minutes for a student questionnaire also was planned at each grade level.

In choosing how to distribute assessment blocks across student achievement booklets, the major goal was to maximize coverage of the framework while ensuring that every student responded to sufficient items to provide reliable measurement of trends in both mathematics and science. A further goal was to ensure that achievement in the mathematics and science content and cognitive domains could be measured reliably. To enable linking among booklets while keeping the number of booklets to a minimum, each block appears in two booklets. TIMSS has used the same booklet design since 2007.

The TIMSS 2019 booklet design shows how the 28 assessment blocks are distributed across 14 student achievement booklets (see Exhibit 4.2). The fourth and eighth grade booklet designs are identical, although the fourth grade blocks contain 18 minutes of assessment items and the eighth grade blocks 22½ minutes. Each student booklet consists of four blocks of items: two blocks of mathematics items, and two of science items. In half of the booklets, the two mathematics blocks come first, and then the two science blocks, and in the other half the order is reversed. Additionally, in most booklets two of the blocks contain trend items from TIMSS 2015 and two contain items newly developed for TIMSS 2019. For example, as may be seen from Exhibit 4.2, students assigned Booklet 1 complete two blocks of mathematics items, M01 and M02, and two blocks of science items, S01 and S02. The items in blocks M01 and S01 are trend items from TIMSS 2015, while those in M02 and S02 are items new for TIMSS 2019. Similarly, students assigned Booklet 2 complete two science blocks, S02 and S03, followed by two mathematics blocks, M02 and M03. S02 and M02 contain the new items and S03 and M03 the trend items.

Countries participating in TIMSS aim for a sample of at least 4,000 students to ensure that there are enough respondents for each item. The 14 student booklets are distributed among the students in each sampled class according to a predetermined order, so that approximately equal proportions of students respond to each booklet.

Exhibit 4.2: TIMSS 2019 Student Achievement Booklet Design—Fourth and Eighth Grades

	Assessment Blocks			
Student Achievement Booklet	Part 1		Part 2	
Booklet 1	M01	M02	S01	S02
Booklet 2	S02	S03	M02	M03
Booklet 3	M03	M04	S03	S04
Booklet 4	S04	S05	M04	M05
Booklet 5	M05	M06	S05	S06
Booklet 6	S06	S07	M06	M07
Booklet 7	M07	M08	S07	S08
Booklet 8	S08	S09	M08	M09
Booklet 9	M09	M10	S09	S10
Booklet 10	S10	S11	M10	M11
Booklet 11	M11	M12	S11	S12
Booklet 12	S12	S13	M12	M13
Booklet 13	M13	M14	S13	S14
Booklet 14	S14	S01	M14	M01

Less Difficult TIMSS Mathematics at Fourth Grade

As described in the introduction to this volume, countries participating in TIMSS 2019 at the fourth grade can choose to administer an assessment with some less difficult blocks than the regular TIMSS fourth grade mathematics assessment. Participants availing of this option administer the fourth grade science assessment as usual, so that student booklets contain a combination of less difficult mathematics items and regular science items. As shown in Exhibit 4.3, the item block design for the less difficult mathematics has the same number of item blocks as the regular mathematics assessment, so that the same block to booklet assignment can be used for both less difficult and regular fourth grade assessments (i.e., the booklet design shown in Exhibit 4.2).

An essential aspect of the less difficult mathematics assessment is that the student achievement results are reported on the same TIMSS achievement scale as the regular mathematics assessment, so that results are comparable regardless of the version of the assessment the students have taken. To support the link between the two versions, the less difficult mathematics assessment includes four blocks of items that also are included in the regular assessment—blocks N02, N06, N08, and N10 in Exhibit 4.3. These correspond to blocks M01, M03, M11, and M13 in the regular assessment. The less difficult assessment capitalizes on its origins in the TIMSS 2015 Numeracy assessment by including eight blocks of items from that assessment—blocks N01, N03, N05, N06, N07, N09, N11, and N13 in Exhibit 4.3. Block N06 was in both the fourth grade TIMSS and the TIMSS Numeracy assessment in 2015.

Exhibit 4.3: TIMSS 2019 Fourth Grade Less Difficult Mathematics—Item Blocks

N01	Trend Block N09 from TIMSS Numeracy 2015
N02	Block M01 in TIMSS 2019 – TIMSS Trend Block M13 from TIMSS 2015
N03	Trend Block N10 from TIMSS Numeracy 2015
N04	New less difficult items for TIMSS 2019
N05	Trend Block N05 from TIMSS Numeracy 2015
N06	Block M03 in TIMSS 2019 – TIMSS and TIMSS Numeracy Trend Block M08/N08 from TIMSS 2015
N07	Trend Block N07 from TIMSS Numeracy 2015
N08	Block M11 in TIMSS 2019 – TIMSS Trend Block M12 from TIMSS 2015
N09	Trend Block N06 from TIMSS Numeracy 2015
N10	Block M13 in TIMSS 2019 – TIMSS Trend Block M14 from TIMSS 2015
N11	Trend Block N02 from TIMSS Numeracy 2015
N12	New less difficult items for TIMSS 2019
N13	Trend Block N03 from TIMSS Numeracy 2015
N14	New less difficult items for TIMSS 2019

Both the regular and less difficult mathematics items will follow the same development guidelines described in the Question Types and Scoring Procedures section with respect to the use of multiple choice and constructed response items.

eTIMSS Assessment Design

The item block design for eTIMSS 2019 (Exhibit 4.4) is similar to the paper and pencil TIMSS design (Exhibit 4.1), with each block in the paperTIMSS design having a counterpart in digital format in the eTIMSS design. The eTIMSS design is more extensive, however, in that it also includes four blocks of problem solving and inquiry (PSI) tasks and items. Blocks ET19DCM01 through ET19DCM14 in Exhibit 4.4 are the digital versions of mathematics blocks M01 through M14 in Exhibit 4.1, and similarly blocks ET19DCS01 through ET19DCS14 are the digital versions of science blocks S01 through S14. Blocks ET19DPSIM1 and ET19DPSIM2 contain mathematics PSIs while blocks ET19DPSIS1 and ET19DPSIS2 contain PSIs for science.

Similar to the paperTIMSS design, eTIMSS blocks ending in the numbers 01, 03, 05, 06, 07, 09, 11, and 13 contain the trend items from the 2015 assessment, although converted to digital format. Blocks ending in numbers 02, 04, 08, 10, 12, and 14 contain items developed for use for the first time in TIMSS 2019. As far as possible these are digital versions of the items in the corresponding paperTIMSS blocks, although adapted to make use of digital components such as "drag and drop," "sorting," etc., as appropriate.

Exhibit 4.4: eTIMSS 2019 Item Blocks—Fourth and Eighth Grades

Mathematics Blocks	Source of Items	Science Blocks	Source of Items
ET19DCM01	Trend Block M13 from TIMSS 2015: digital format	ET19DCS01	Trend Block S13 from TIMSS 2015: digital format
ET19DCM02	New items for TIMSS 2019: digital format	ET19DCS02	New items for TIMSS 2019: digital format
ET19DCM03	Trend Block M08 from TIMSS 2015: digital format	ET19DCS03	Trend Block S08 from TIMSS 2015: digital format
ET19DCM04	New items for TIMSS 2019: digital format	ET19DCS04	New items for TIMSS 2019: digital format
ET19DCM05	Trend Block M09 from TIMSS 2015: digital format	ET19DCS05	Trend Block S09 from TIMSS 2015: digital format
ET19DCM06	Trend Block M10 from TIMSS 2015: digital format	ET19DCS06	Trend Block S10 from TIMSS 2015: digital format
ET19DCM07	Trend Block M11 from TIMSS 2015: digital format	ET19DCS07	Trend Block S11 from TIMSS 2015: digital format
ET19DCM08	New items for TIMSS 2019: digital format	ET19DCS08	New items for TIMSS 2019: digital format

Exhibit 4.4: eTIMSS 2019 Item Blocks—Fourth and Eighth Grades (Continued)

Mathematics Blocks	Source of Items	Science Blocks	Source of Items
ET19DCM09	Trend Block M04 from TIMSS 2015: digital format	ET19DCS09	Trend Block S04 from TIMSS 2015: digital format
ET19DCM10	New items for TIMSS 2019: digital format	ET19DCS10	New items for TIMSS 2019: digital format
ET19DCM11	Trend Block M12 from TIMSS 2015: digital format	ET19DCS11	Trend Block S12 from TIMSS 2015: digital format
ET19DCM12	New items for TIMSS 2019: digital format	ET19DCS12	New items for TIMSS 2019: digital format
ET19DCM13	Trend Block M14 from TIMSS 2015: digital format	ET19DCS13	Trend Block S14 from TIMSS 2015: digital format
ET19DCM14	New items for TIMSS 2019: digital format	ET19DCS14	New items for TIMSS 2019: digital format
ET19DPSIM1	New Math PSI tasks TIMSS 2019: digital format	ET19DPSIS1	New Science PSI tasks TIMSS 2019: digital format
ET19DPSIM2	New Math PSI tasks TIMSS 2019: digital format	ET19DPSIS2	New Science PSI tasks TIMSS 2019: digital format

Exhibit 4.5 shows the eTIMSS block combinations (as student booklets are known in eTIMSS) that are assigned to individual students, and as such is the eTIMSS counterpart to Exhibit 4.2 for paperTIMSS. For example, block combination ET19DCBC01 for eTIMSS includes mathematics blocks ET19DCM01 and ET19DCM02 and science blocks ET19DCS01 and ET19DCS02, just as Booklet 1 contains blocks M01, M02, S01, and S02 for paperTIMSS. The eTIMSS design contains two extra block combinations, ET19DCBC15 and ET19DCBC16, to accommodate the PSI tasks. Similar to paper TIMSS, the 16 eTIMSS block combinations are distributed among students in each sampled classroom according to assignments predetermined by the within-school sampling software.

Exhibit 4.5: eTIMSS 2019 Student Achievement Block Combination (Booklet) Design—Fourth and Eighth Grades

	Assessment Blocks			
Student Block Combination	Part 1		Part 2	
ET19DCBC01	ET19DCM01	ET19DCM02	ET19DCS01	ET19DCS02
ET19DCBC02	ET19DCS02	ET19DCS03	ET19DCM02	ET19DCM03
ET19DCBC03	ET19DCM03	ET19DCM04	ET19DCS03	ET19DCS04
ET19DCBC04	ET19DCS04	ET19DCS05	ET19DCM04	ET19DCM05
ET19DCBC05	ET19DCM05	ET19DCM06	ET19DCS05	ET19DCS06
ET19DCBC06	ET19DCS06	ET19DCS07	ET19DCM06	ET19DCM07
ET19DCBC07	ET19DCM07	ET19DCM08	ET19DCS07	ET19DCS08
ET19DCBC08	ET19DCS08	ET19DCS09	ET19DCM08	ET19DCM09
ET19DCBC09	ET19DCM09	ET19DCM10	ET19DCS09	ET19DCS10
ET19DCBC10	ET19DCS10	ET19DCS11	ET19DCM10	ET19DCM11
ET19DCBC11	ET19DCM11	ET19DCM12	ET19DCS11	ET19DCS12
ET19DCBC12	ET19DCS12	ET19DCS13	ET19DCM12	ET19DCM13
ET19DCBC13	ET19DCM13	ET19DCM14	ET19DCS13	ET19DCS14
ET19DCBC14	ET19DCS14	ET19DCS01	ET19DCM14	ET19DCM01
ET19DCBC15	ET19DPSIM1	ET19DPSIM2	ET19DPSIS1	ET19DPSIS2
ET19DCBC16	ET19DPSIS2	ET19DPSIS1	ET19DPSIM2	ET19DPSIM1

Student Testing Time

As summarized in Exhibit 4.6, each student completes one student achievement booklet or block combination consisting of two parts, followed by a student questionnaire. The individual student response burden for the TIMSS 2019 assessment is the same as it has been since TIMSS 2007—that is, 72 minutes for the assessment and 30 minutes for the questionnaire at the fourth grade, and 90 minutes and 30 minutes, respectively, at the eighth grade.

Exhibit 4.6: TIMSS 2019 Student Testing Time—Fourth and Eighth Grades

Activity	Fourth Grade	Eighth Grade
Student Achievement Booklet—Part 1	36 minutes	45 minutes
Break		
Student Achievement Booklet—Part 2	36 minutes	45 minutes
Break		
Student Questionnaire	30 minutes	30 minutes

References

Foy, P., & Yin, L. (2016). Scaling the TIMSS 2015 achievement data. In M.O. Martin, I.V.S. Mullis, & M. Hooper (Eds.), *Methods and Procedures in TIMSS 2015* (pp. 13.1–13.62). Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://timss.bc.edu/publications/timss/2015-methods/chapter-13.html

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TIMSS 2019 Assessment Frameworks
APPENDIX A

Acknowledgments

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APPENDIX A

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With each new assessment cycle of a study, one of the most important tasks is to update the assessment frameworks. Updating the TIMSS assessment frameworks for 2019 began in September of 2016, and has involved extensive input and reviews by individuals at the TIMSS & PIRLS International Study Center, IEA, the TIMSS 2019 National Research Coordinators, and the two TIMSS expert committees—the TIMSS 2019 Science and Mathematics Item Review Committee and the TIMSS 2019 Questionnaire Item Review Committee. Of all the individuals around the world that it takes to make TIMSS a success, the intention here is to specifically acknowledge some of the many persons who had particular responsibility and involvement in developing and producing the TIMSS 2019 Assessment Frameworks.

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The Science and Mathematics Item Review Committee (SMIRC), comprised of internationally recognized mathematics and science experts, reviewed and recommended updates for the TIMSS 2019 Mathematics and Science Frameworks. The SMIRC also reviews the TIMSS 2019 items at key points in the development process.

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APPENDIX B

Example Restricted Use Items

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APPENDIX B

Example Restricted Use Items

Grade 4 Mathematics

M041291

Subtract:

428 – 176

Answer: 252

$$\begin{array}{r} {\scriptstyle 3\ 12} \\ \cancel{4}\cancel{2}8 \\ -\ 176 \\ \hline 252 \end{array}$$

M051140

Charlie is 24 years old.

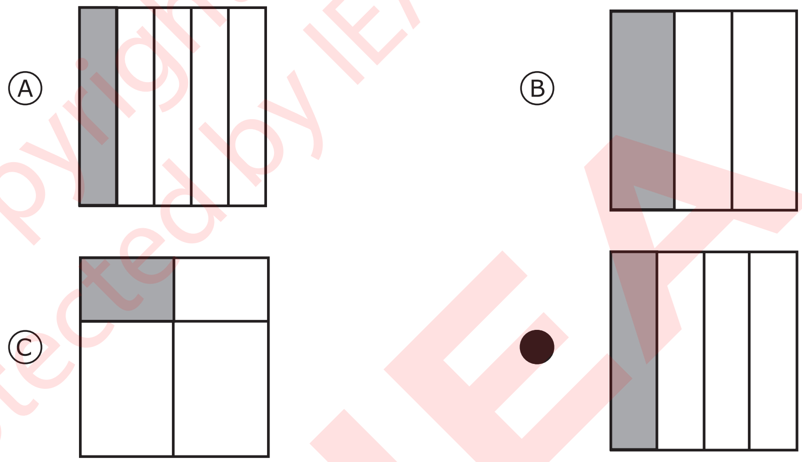
He is ■ years older than Jenny.

Which of the following represents Jenny's age?

- ● 24 – ■
- Ⓑ ■ + 24
- Ⓒ ■ – 24
- Ⓓ 24 × ■

M041298

Which rectangle is $\frac{1}{4}$ shaded?



M041124

Rule: To find the number in Column B, multiply the number in Column A by 4, then add 1.

Use this rule to fill in the table below.

Column A	Column B
2	9
5	21

$2 \times 4 + 1 = 9$

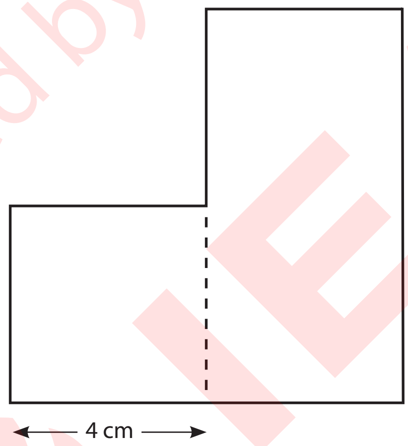
$5 \times 4 + 1 = 21$

This shape consists of a square and a rectangle.

The width of the rectangle is the same as the width of the square.

The length of the rectangle is twice as long as its width.

Find the perimeter of the shape.



Ⓐ 28 cm

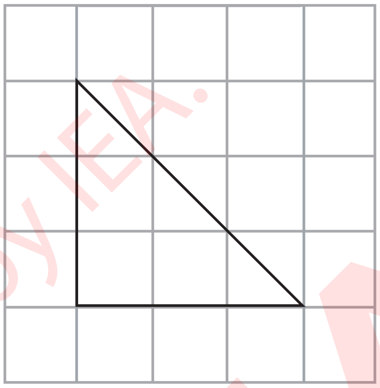
● 32 cm

Ⓒ 36 cm

Ⓓ 40 cm

M051093

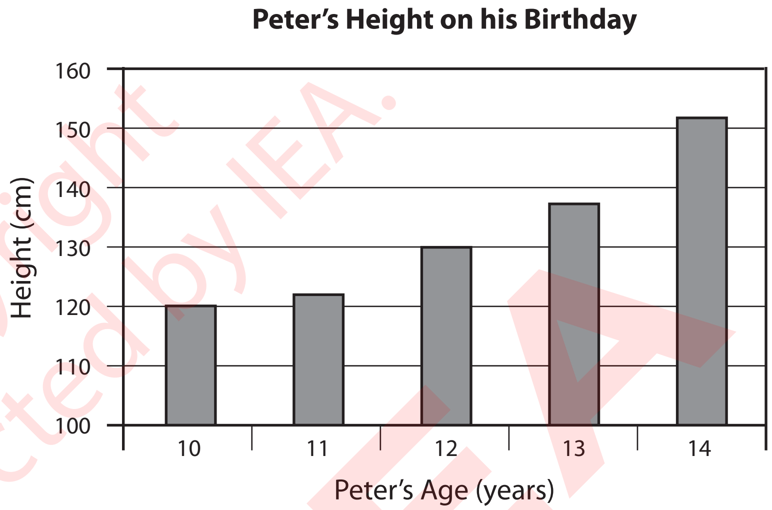
M041264



The triangle is on a centimeter grid. What is its area?

- Ⓐ 4.5 square centimeters
- Ⓑ 6 square centimeters
- Ⓒ 9 square centimeters
- Ⓓ 9.5 square centimeters

M041191



Between which ages did Peter's height increase most?

Ⓐ 10 and 11

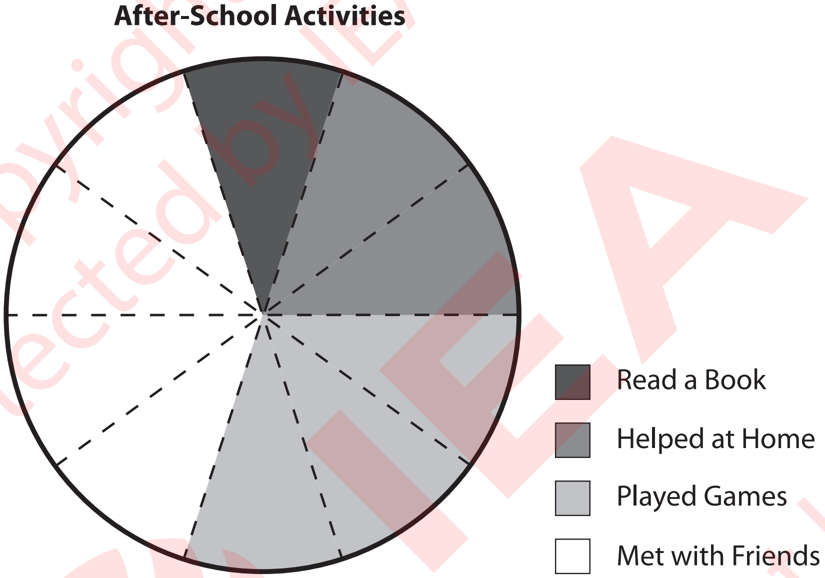
Ⓑ 11 and 12

Ⓒ 12 and 13

● 13 and 14

This pie chart shows what some students did after school.

The chart is divided into 10 equal sections.



20 students read a book. How many met with friends?

Ⓐ 40

Ⓑ 60

● 80

Ⓓ 100

M051077

Grade 8 Mathematics

Write this as a decimal number.

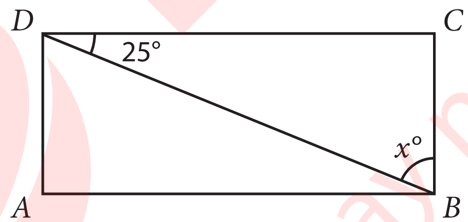
$8 + 50 + \frac{3}{100} + \frac{1}{10}$

$58 + 0.03 + 0.1$

$58 + 0.13 = 58.13$

Answer: 58.13

M042081



ABCD is a rectangle. What is the value of x?

Ⓐ 25

Ⓑ 45

● 65

Ⓓ 75

M042203

M042066

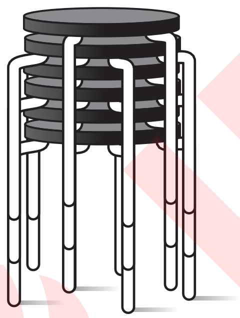
Write in the missing term in this sequence:

1, 1, 2, 3, 5, 8, 13, 21, 34, 55.

1+1=2
1+2=3
2+3=5
5+8=13
8+13=21

M052142

In John's house there are stools stacked together.



One stool is 49 cm high.

When 2 stools are stacked the stools are 55 cm high.

How high above the ground is the top of a stack of 6 stools?

- ● 79 cm
- (B) 85 cm
- (C) 110 cm
- (D) 165 cm

Peter and Tom went to the same shop to buy some books and pens.

Peter bought 5 books and 2 pens and paid 74 zeds.

Tom bought 1 pen and 3 books and paid 42 zeds.

Which pair of equations could represent this situation?

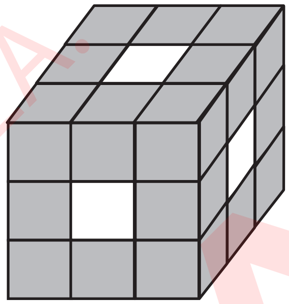
Ⓐ $5x + 2x = 74$
$y + 3y = 42$

Ⓑ $5x + 2y = 74$
$x + 3y = 42$

● $5x + 2y = 74$
$3x + y = 42$

Ⓓ $5y + 2y = 74$
$3x + y = 42$

M052090



A cube had 27 small, gray cubes. First, the small cube at the center of each face was removed. Then, the small cube in the center was removed.

How many cubes were left in the solid?

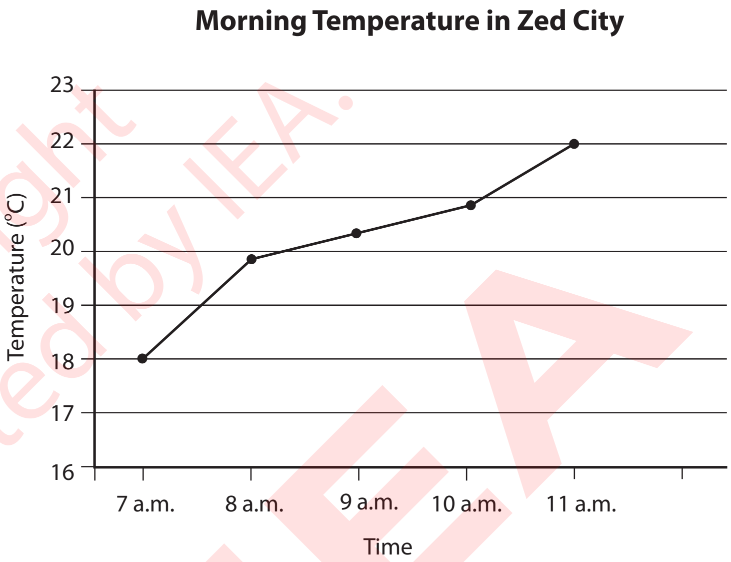
Ⓐ 4

Ⓑ 16

● 20

Ⓓ 24

M042271

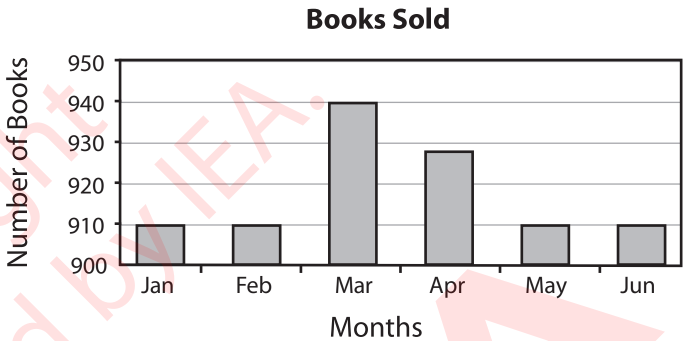


The graph shows hourly temperatures from 7 a.m. to 11 a.m.

Estimate the temperature at 9:30 a.m.

Answer: 20.5 °C

M042224



A salesman looked at the graph showing his sales of books for the first 6 months of 2004, and said, “In March, I sold four times as many books as I sold in February.”

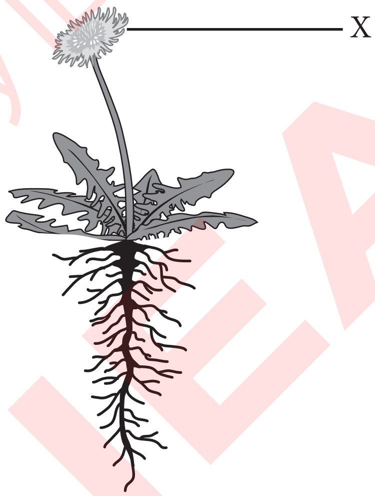
Explain whether you agree or disagree with the salesman, and give a reason.

I disagree because the salesman sold 910 books in February and 940 books in March. 910 times 4 does not equal 940.

M042164

Grade 4 Science

The diagram shows a flowering plant.



What is a function of the part of the plant labeled X?

Ⓐ to make food

Ⓑ to transport food

● to produce seeds

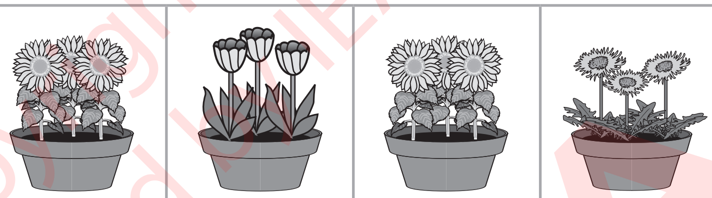
Ⓓ to absorb water

S041223

S051008

Sara wants to know if fertilizer has any effect on the growth of plants.

She has four pots containing the same type of soil. She puts plants in each pot and adds fertilizer to two of the pots as shown below.



Pot 1	Pot 2	Pot 3	Pot 4
Fertilizer	Fertilizer	No fertilizer	No fertilizer

Which two pots should she compare to find out if fertilizer has any effect on the growth of plants?

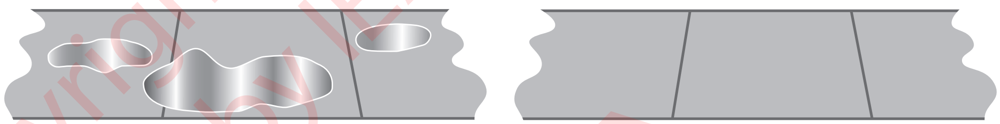
Pot ___1___ and Pot ___3___.

Explain your answer.

Pots 1 and 3 have the same type of flower

Figure 1 shows some puddles of water on a concrete sidewalk in the morning. In the afternoon, the concrete sidewalk was dry as shown in Figure 2.

Figure 1 Figure 2



morning afternoon

What happened to the water?

● It went into the air.

Ⓑ It turned to dust.

Ⓒ It was used by trees.

Ⓓ It spilled into the road.

S051105

Which material is the best conductor of heat?

Ⓐ wood

● metal

Ⓒ glass

Ⓓ plastic

S041191

Mike took four items from his kitchen and tested them to see whether they dissolved in water. He also touched them to see how hard they were. He wrote his results in a table, as shown below.

	Hard	Soft
Dissolves in water	Sugar cube	Honey
Does not dissolve in water	Metal spoon	Sponge

Mike found four more items, as shown below.

Which item is in the same group as the sponge?

Ⓐ jelly

Ⓑ rock salt

● rubber ball

Ⓓ glass bottle

S041050

The pictures below show a shadow at three different times of the day.

Explain why the shadows changed.

The shadows changed because the sun changed position in the sky

S041113

Water flows across Earth's surface.

In which direction does it flow?

- ● mountains → rivers → oceans
- Ⓑ oceans → mountains → rivers
- Ⓒ rivers → oceans → mountains
- Ⓓ mountains → oceans → rivers

S051102

Grade 8 Science

Look at the list of organisms.

fish **ant** **frog** **spider** **earthworm** **bird** **whale**

Classify the organisms into two groups based on a physical or behavioral characteristic.

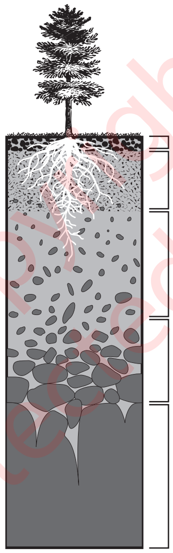
Group 1	Group 2
fish frog bird whale	ant spider earthworm

Write down the characteristic you used to classify the organisms.

Group 1 has a backbone and group 2 does not have a backbone

S042005

The diagram shows layers in the soil.



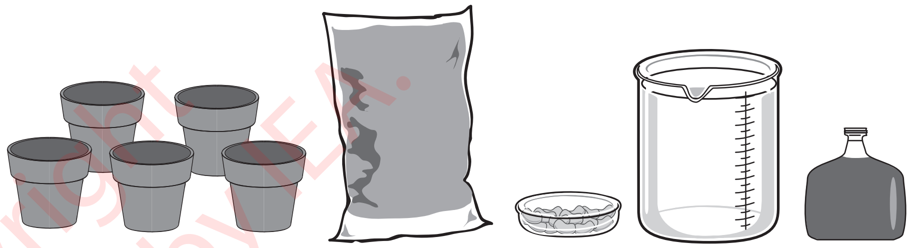
Most plants have roots that grow in the topsoil, but some have roots that reach into the subsoil.

Write two advantages for a plant to have long roots that go down into the subsoil.

1. Long roots anchor the plant better.

2. Long roots can reach more water.

S052116



Using the equipment above, describe an investigation to find out how fertilizer affects the growth of plants.

Put the same amount of soil in each pot.
Add 2 seeds to each pot.
Add the same amount of water to each pot and the same amount of fertilizer to 3 pots. Do not add fertilizer to the other 2 pots.

S042319

The table below lists some properties of water, mercury, and iron.

	State at Room Temperature (20°C)	Melting Point (°C)	Boiling Point (°C)
Water	Liquid	0	100
Mercury	Liquid	–39	357
Iron	Solid	1,530	2,450

What is the state (solid, liquid, or gas) of water, of mercury, and of iron at 350°C?

Water: gas

Mercury: liquid

Iron: solid

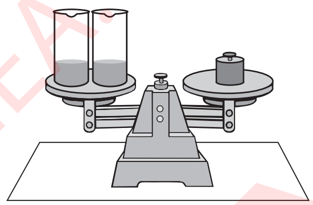
S052145

Which is an example of a chemical process that releases energy?

- Ⓐ water boiling
- Ⓑ raw egg cooking
- ● oil lamp glowing
- Ⓓ white sugar dissolving

S052063

Two beakers, one containing hydrochloric acid and the other containing sodium hydroxide exactly balance a weight, as shown in the diagram.



The two solutions are carefully mixed together, and the empty beaker is put back on the balance.

Look at the diagrams below.

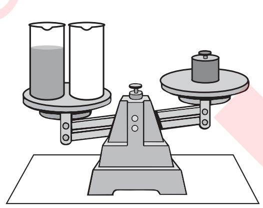


Diagram A

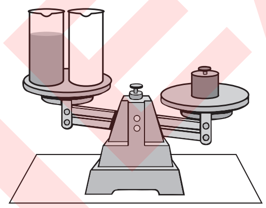


Diagram B

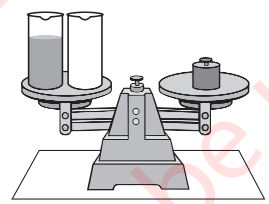


Diagram C

Which diagram shows the balance after the solutions have been mixed?

(Check one box.)

☐ Diagram A

☐ Diagram B

☒ Diagram C

Explain your answer.

When 2 chemicals are combined, the mass is the same before and after they are mixed.

S042104

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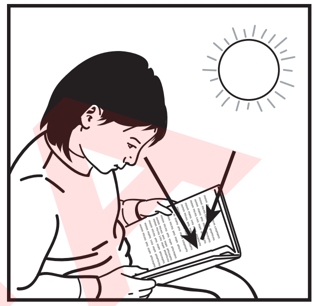
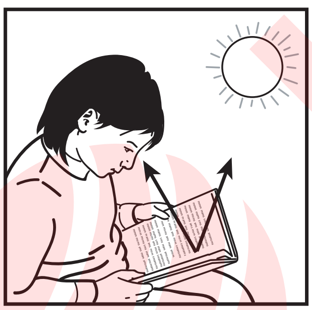
S042216

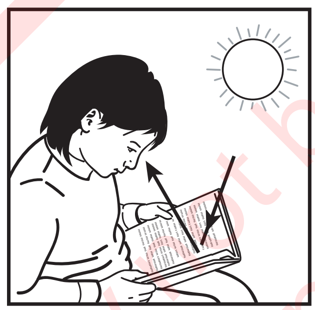
A student is reading a book.

Which diagram shows the direction in which light travels so that she can read the book?

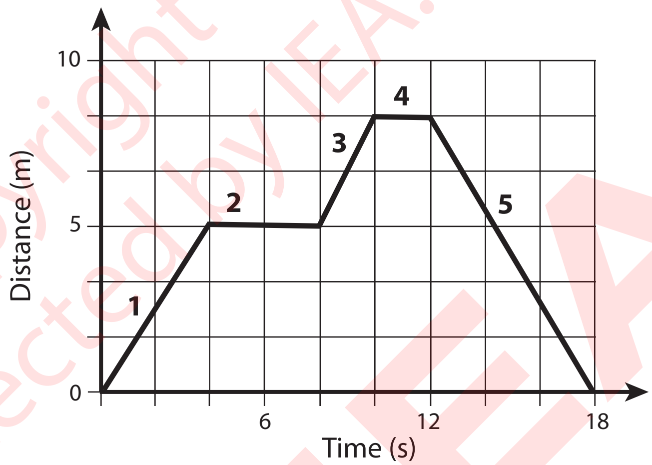
Ⓐ


Ⓑ


Ⓒ


●


A toy car moves in a straight line. A graph of the car's distance from the starting point over 18 seconds is shown below.

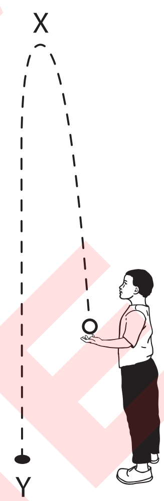


Which of the following best describes the motion of the toy car during each of the five segments?

	Segment				
	1	2	3	4	5
A	moving forward	not moving	moving forward	not moving	moving backward
B	not moving	moving backward	not moving	moving backward	moving forward
C	moving forward	not moving	moving backward	not moving	moving backward
D	moving backward	not moving	moving backward	not moving	moving forward

S062268

Jeffrey throws a ball up into the air, as shown in the diagram. It reaches its highest point at X and then falls straight down to the ground at point Y. The ball then bounces straight up again.



A. What force causes the ball to fall from point X to point Y?

gravity

B. When the ball bounces up again, will it bounce higher than, lower than, or to the same height as point X?

(Check one box.)

- [ ] Higher than point X
- [x] Lower than point X
- [ ] Same height as point X

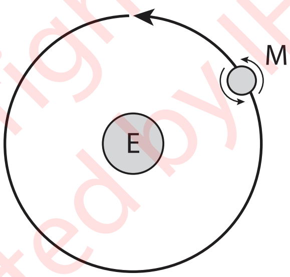
Explain your answer.

The ball loses energy when it bounces, so it cannot bounce as high as X the second time.

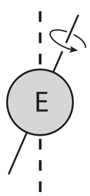
S042293

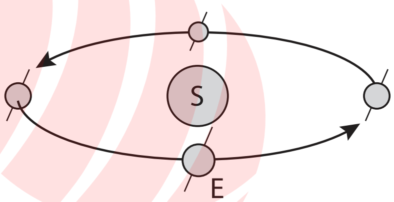
Which diagram below can be used to explain the changing seasons during the year for most places north or south of the equator? In the diagrams, S is the Sun, E is the Earth, and M is the Moon.

(A)

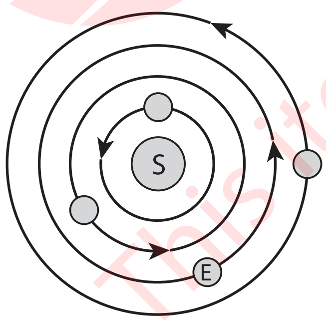


(B)





(D)



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